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Engineering Library

JUL 3 1922

ENGINEERING:

An Illustrated Weekly Journal.

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VOL. CXIII.—No. 2946.] *LONDON: FRIDAY, JUNE 16, 1922.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 3½d.

Aveling & Porter, Ltd.,
ROCHESTER.
9063
Steam Road Rollers & Tractors.

A. G. Mumford, Ltd.,
CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See advertisement pages 25 and 29.
PATENT WATER-TUBE BOILERS, AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2170

Dredging Plant
OF ALL DESCRIPTIONS.
FLOATING CRANES, COAL BUNKERING VESSELS.
Werf Conrad, HAARLEM, HOLLAND.
Agents: MARINE WORKS, LTD., FRIARS HOUSE, 39-41, NEW BROAD ST., LONDON, E.C.2.
See half-page Advert. last week and next week. 675

Cranes.—Electric, Steam, HYDRAULIC and HAND, of all types and sizes.
GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 9048

STEEL TANKS, PIPES, GASHOLDERS, &c.
Thos. Piggott & Co., Limited, BIRMINGHAM. 7411
See Advertisement last week, page 93.

"Spencer-Hopwood" Patent WATER TUBE **Boilers.** *See page 76.* 577
Sole Makers: SPENCER-BONECOURT, LTD., Parliament Mansions, Victoria St., London, S.W.

Tank Locomotives.
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO. LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 9044

Cochran MULTITUBULAR AND CROSS-TUBE TYPES **Boilers.**
See page 17. 9047

Petter Oil Engines.
For Paraffin and Crude Oil.
Sizes 1½ B.HP. and upwards.
Petters Limited, Yeovil.
Sizes 25 to 500 B.HP.
Vickers-Petters, Ltd., Ipswich
See advertisement alternate weeks. 9335

Invincible Gauge Glasses.
BUTTERWORTH BROS., Ltd., Newton Heath Glass Works, Manchester. Oct 9753

Electric Cranes.
9063
S. H. HEYWOOD & CO., LTD., REDDISH.

Fuller, Horsey, Sons & Cassell.
SPECIALISTS in the SALE AND VALUATION of 1834
PLANT AND MACHINERY and ENGINEERING WORKS.
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Iron and Steel
Tubes and Fittings.
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 8746
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 36, Robertson Street, Glasgow.
See Advertisement page 77, June 9.

Yarrow & Co. (1922), Ltd.,
SHIPBUILDERS AND ENGINEERS, GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF EXCEPTIONAL SHALLOW DRAUGHT.
Repairs on Pacific Coast by YARROWS, LIMITED, Victoria, British Columbia. 9063
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

Campbells & Hunter, Ltd.
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Worm Wheels cut up to 13 ft. diam.
Bevel and Mitre Wheels planed up to 3 ft. diam.
Spur Wheels cut up to 9 ft. diam.
DOLPHIN FOUNDRY, LEEDS. 4547

VOSPER & CO., LTD.,
PORTSMOUTH.
SHIP & LAUNCH BUILDERS, Oct 3351
ENGINEERS & BOILER MAKERS.

Cement.—Maxted & Knott,
LTD., Consulting Cement Engineers, ADVISE GENERALLY on proposed Cement Schemes FOR ENGLAND AND ABROAD. ADVICE ONLY. Highest references. Established 1890.
Address, BURNETT AVENUE, HULL.
Cablegrams: "Energy, Hull." 9762

OIL FUEL APPLIANCES,
Systems
PRESSURE, AIR, STEAM
For Boilers of all types.
KERMODES LIMITED,
35, The Temple, Dale Street, Liverpool.
Naval Outfits a Speciality, also for Merchant Ships, for Factories, Locomotives, and Industrial Process Furnaces of all kinds.
Supplied to the British and other Governments.
Telephone No.: Central 2832.
Telegrams: "Warmth." 4078

Locomotives Tank Engines
designed and constructed by
MANNING, WARDLE AND COMPANY, LIMITED, Boyne Engine Works, Leeds Oct 2487
See their Illus. Advertisement, page 97, last week.
RAILWAY AND TRAMWAY ROLLING STOCK.
Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Oct 3383

R. Y. Pickering & Co., Ltd.,
(ESTABLISHED 1864.)
BUILDERS of RAILWAY CARRIAGES & WAGONS.
MAKERS of WHEELS and AXLES of all kinds.
RAILWAY WAGONS FOR HIRE.
Chief Works and Offices:
WISHAW, near GLASGOW.
London Office: Oct 8353
3, VICTORIA STREET, WESTMINSTER, S.W.

Henry Butcher & Co.,
AUCTIONEERS, VALUERS AND SURVEYORS for ENGINEERING AND ALLIED TRADES and INDUSTRIAL PROPERTIES. 9666
63 and 64, CHANCERY LANE, LONDON, W.C.2.

Electric Transporters.
S. H. HEYWOOD & CO., LTD., 9063
REDDISH.

John H. Wilson & Co., Ltd.,
Birkenhead.
See Illustrated Advertisement Page 100, Jan. 26, 1921.

Locomotive Shunting Cranes

Steam and Electric Cranes
EXCAVATORS, CRANE-SKYVINS, GRABS, CONCRETE-MIXERS,
SHIPS' WINDLASSES, WINCHES, and DECK MACHINERY. 627
LISTS OF STANDARD SIZES ON APPLICATION.
London Office: 15, VICTORIA STREET, S.W.1.

John Bellamy, Limited,
MILLWALL, LONDON, E. 1216
GENERAL CONSTRUCTIONAL ENGINEERS,
Boilers, Tanks, & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETED STEAM AND VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

Tubes and Fittings.

Stewarts and Lloyds, Ltd.,
Glasgow and Birmingham.
See Advertisement page 50. 9063

Economy!
HIGH BOILER EFFICIENCIES ARE OBTAINED BY INSTALLING
Todd Oil Burners
FUEL OIL BURNING SYSTEMS, HEATERS, STRAINERS.
49-51, EASTCHEAP, LONDON, E.C.3.
TODD SHIPYARDS CORPORATION,
Builders of Steam and Motor Ships, Repairers, Electric Drive Installations.
Twenty-one Floating Docks, Two Graving Docks, Twelve Shipways.
25, Broadway, New York, U.S.A. 9060

The Glasgow Railway Engineering Company,
GOVAN, GLASGOW. LTD.,
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 840

FOR
Drop Forgings
write
GARTSHERRIE ENGINEERING & FORGE CO., 50, Wellington Street, Glasgow. 9074

ON ADMIRALTY LIST.
John Kirkaldy, Ltd.,
London Office: 101, LEADENHALL ST., E.C.3.
Works: BURNT MILL, near HARLOW, ESSEX.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice Making Machinery.
Feed Water Heaters.
Evaporators.
Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers.
&c. &c. 9604

Electric Lifts
(UP TO 35 TONS.)
9063
S. H. HEYWOOD & CO., LTD.
REDDISH.

Hardening & Heat Treatment.
Any class of tools. H. S. Chasers for adjustable die heads. Case hardening, colouring, etc. We can case harden Cast Iron for gauges, press tools, etc. Write us for particulars, Reliable Work! Right Prices! Delivery to promise!
OWEN & CRISP.
Engineers and Engineers' Agents, 64, Basinghall Street, London, E.C.2.
Telephone:—London Wall 5066. 9650

Diesel Engines, Six Cylinder,
Two and Four stroke, 850, 1000, 1200 H.P., excellent condition. Dynamos for above 250 or 500 volts, D.C. Immediate delivery and low price.
Two 500 Kw. Parsons Turbine Sets, 250 or 500 volts, D.C., with condensing plant and spare armature. Price £2200.
Electrical driven Centrifugal, Ram and other Pumps from 1½ in.–10 in. outlet.
JENNINGS, 9743
West Walls, Newcastle-on-Tyne.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STRAM AND GAS KETTLES, } Row's Patents.
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 9733

Yarrow Patent Water-tube Boilers.
9064
Messrs. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO. (1922), LTD., SCOTSTOUN, GLASGOW.

Matthew Paul & Co., Ltd.
LEVENFORD WORKS, **Dumbarton.** 7621
See Full Page Advt., page 58, May 26.

Forgings.
Walter Somers, Limited, HALESOWEN. 9116

Taylor & Challen Presses
9196
About 200 NEW PRESSES in Stock in our Showrooms for immediate delivery at specially Reduced Prices.
TAYLOR & CHALLEN, LTD., Engineers, Constitution Hill, BIRMINGHAM.
See Full page Advertisement, page 42, May 26.

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 56. 2402

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 609

GRAPHITED OIL. **"OILDAG"** (Reg.) BRAND.
GRAPHITED WATER. **"AQUADAG"** (Reg.) BRAND.
GRAPHITED GREASE. **"GREDAG"**
9205
E. G. Acheson Ltd.,
Dept. R., (Sole Manufacturers.) Works:
40, WOOD ST., S.W.1. PLYMOUTH.

Locomotive Traversers
(ELECTRIC).
9063
S. H. HEYWOOD & CO., LTD.,
REDDISH.

P. & W. MacLellan, Limited,
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 120, Trongate, GLASGOW. Oct 8247
Registered Offices: Clutha House, 10, Princes St., Westminster, London, S.W.1.

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
9727
See half-page Advertisement page 96, June 9.

The Manchester Steam Users' ASSOCIATION.
For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by SIR WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 598

Finsbury Technical College, LEONARD STREET, CITY ROAD, E.C. 2.
Dean for the Session, 1921-22.
PROFESSOR W. H. BOCLES, D.Sc., F.R.S.
The College provides practical scientific training for students who desire to become Civil, Mechanical or Electrical Engineers, or Chemists.
Candidates are required to pass an Entrance Examination in Mathematics and English, but the Matriculation Certificate of any British University, and certain other qualifications, are accepted in lieu of it. The next ENTRANCE EXAMINATION will be held on TUESDAY, SEPTEMBER 19th. Applications for admission should be forwarded to the College on forms to be obtained from the REGISTRAR. The Programme of the College is under revision and will be issued shortly. U 480

Correspondence Courses for Inst. Civil Engrs., Inst. Mech. E., London Univ. (Matric., Inter., B.Sc.), and ALL ENGINEERING EXAMINATIONS personally conducted by MR. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 6/11, TRAFFORD CHAMBERS, 59, SOUTH JOHN STREET, LIVERPOOL. 578

Inst. C.E., I. Mech. E., B.Sc., and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., M.E.E., A.M.Inst.C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Thousands of successes during the last sixteen years. Courses may commence at any time.—99, Victoria St., Westminster, S.W. Tel. 4780 Victoria. 745

Inst. C.E. Exams.—Successes as usual last Exam. by Correspondence Coaching. Successes by hundreds, several prizes. Sec. "O" embraces 25 years' professional experience. Address, 7434, Offices of ENGINEERING.

Powering of Vessels.—A Practical Course of Instruction by Correspondence.—Address, for particulars and terms, 748, Offices of ENGINEERING.

TENDERS.

BENGAL-NAGPUR RAILWAY COMPANY, LIMITED.

The Directors are prepared to receive

Tenders for the following:—
8486 tons STEEL FLAT FOOTED RAILS, and
365½ tons STEEL FISH PLATES.

Specifications and Forms of Tender can be obtained at the Company's Offices, 132, Gresham House, Old Broad Street, London, E.C. 2, on or after 14th June, 1922.

A fee of £1 1s. will be charged for the specifications, which will not be returned.

Tenders must be submitted not later than noon on Wednesday, 28th June, 1922.

The Directors do not bind themselves to accept the lowest or any Tender.

By Order of the Board,
T. R. WYNNE, U 474
Managing Director.

COUNTY OF LONDON.

REPAIRS TO PAVEMENTS—BLACKWALL AND ROTHERHITHE TUNNELS.

Tenders are Invited for REPAIRS to the PAVEMENTS of Blackwall and Rotherhithe Tunnels.

The Specification, Form of Tender, etc., may be obtained from the Chief Engineer of the Council at Gloucester House, 19, Charing Cross Road, W.C.2, upon payment to the Cashier of the Council of the sum of 5s. This amount will be returnable only if the tender be shall have sent in a *bona fide* Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the contract documents may be inspected before payment of the fee.

Tenders should be addressed to the Clerk of the Council and delivered at the County Hall, Westminster Bridge, S.E., not later than Four p.m. on Monday, 26th June, 1922. No Tender received after that time will be considered.

The Council does not bind itself to accept the lowest or any Tender.

JAMES BIRD,
Clerk of the London County Council. U 469

ROYAL BURGH OF KIRKCALDY.

ELECTRICITY WORKS, VICTORIA ROAD.

The Provost, Magistrates and Council invite

Tenders for the following WORK:—

SPECIFICATION No. 2. CONVERTING PLANT.

A copy of the Specification can be seen at and obtained from the Offices of Messrs. KENNEDY & DONKIN, 17, Victoria Street, Westminster, S.W. 1, on and after Thursday, June 15th, upon payment of a deposit of £2 2s. (cheque, postal or money order). An additional copy of the Specification can be obtained upon payment of a deposit of £1 1s. Those deposits will be returned after the receipt of a *bona fide* Tender, and on the return of the Specification.

Tenders on the prescribed Form, enclosed in sealed envelopes, and addressed on the outside:—"Electricity Supply. Tender to Specification No. 2," must be delivered at the Office of the undersigned not later than Ten a.m. on Monday, 10th July, 1922.

The Council do not bind themselves to accept the lowest or any Tender.

W. L. MACINDOE, Esq.,
Town Clerk's Office,
Kirkcaldy.
June, 1922. U 483

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to Noon on Wednesday, 5th July,

Tenders for the Supply of
1. SPRING AND FERRULE STEEL.
2. WROUGHT IRON OR STEEL PIPING.
3. FERRO MANGANESE AND FERRO SILICON.

Tenders must be made on forms, copies of which, with Specification, can be obtained at these offices on payment of 20s. each for Nos. 1, and 10s. each for Nos. 2 and 3 (which will not be returned).

The Directors do not bind themselves to accept the lowest or any Tender.

S. G. S. YOUNG,
Secretary.

Offices:—
The White Mansion,
91, Petty France,
Westminster, S.W. 1.
12th June, 1922. U 473

METROPOLITAN WATER BOARD.

POSITIVE WATER METERS.

The Metropolitan Water Board invite

Tenders for the Supply of the following quantities of POSITIVE METERS:—
250 ¾-in.; 150 ¾-in.; 100 1-in.; 100 1½-in.; 50 2-in.; 50 3-in.

Forms of Tender and Specification may be obtained from the Chief Engineer, Metropolitan Water Board, New River Head, 173, Rosebery Avenue, E.C. 1, by personal application (Room 150) or upon forwarding a stamped addressed brief envelope.

Tenders enclosed in sealed envelopes addressed to the Clerk of the Board, Metropolitan Water Board, New River Head, 173, Rosebery Avenue, E.C. 1, and endorsed "Tender for Meters," must be delivered at the offices of the Board not later than Eleven a.m. on Tuesday, 20th June, 1922.

The Board do not bind themselves to accept the lowest or any Tender.

W. MOON,
Clerk of the Board.

Offices of the Board,
New River Head,
173, Rosebery Avenue, E.C. 1.
1st June, 1922. U 409

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED,

are prepared to receive

Tenders for the Supply of:—
1. STEEL SCREW COUPLINGS.
2. MILD STEEL.
3. SPARE PARTS for Carriage Underframes and Wagons.
4. WHITE LEAD.

Specifications and forms of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W. 1.

Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked "Tenders for Steel Screw Couplings," or as the case may be, must be left with the undersigned not later than Twelve noon on Friday, the 30th June, 1922.

The Directors do not bind themselves to accept the lowest or any Tender.

A charge, which will not be returned, will be made of 10/- for each copy of Specifications No. 1, 2, 3 & 4.

Copies of the Drawings may be obtained at the office of Messrs. Robert White & Partners, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W. 1.

A. MUIRHEAD,
Managing Director.

91, Petty France, S.W. 1.
14th June, 1922. U 492

MIDLAND GREAT WESTERN RAILWAY OF IRELAND.

CONTRACTS FOR 1922.

The Directors of the Midland Great Western Railway of Ireland Company are prepared to receive

Tenders for the Supply of the undermentioned STORES. The Contracts to commence from the 1st of July next, and to be for six months.

	No. of Form.		No. of Form.
Asbestos & Packing	1	Lime	22
Barrows and Trucks	2	Leather and Belting	23
Baskets and Mats	3	Lamps and Tinware	24
Brushes, Brooms, &c.	4	Locks, Rainwater Goods & Hardware	25
Brass Fittings for Gas and Water	5	Oils	26
Bolts, Nuts and Rivets	6	Paints, Colours and Wallpaper	27
Bricks, Slates, Earthenware Pipe, &c.	7	Rail Fastenings, Iron	29
Chain	8	" " steel	30
Cement	9	Screws, Split Pins, Nails, &c.	31
Candles and Soap	10	Steel Castings	35
Carriage Fittings	11	Staffordshire Iron, Wire, &c.	36
do. Trimmings	12	Soft Goods	38
Clothing	12A	Timber, &c.	39
Creosote Oil	13	Tools	40
Glass	16	Varnishes	43
Gas Mantles, &c.	18	Wagon Covers and Tarpaulins	43
Iron & Steel Forgings	19	Wicking	44
Iron Castings	20		
India Rubber Goods	21		

Forms of Tender can be obtained, on payment of 6d. each, from the STOREKEEPER, GENERAL STORES DEPARTMENT, BROADSTONE STATION, DUBLIN. *Please do not send Stamps.*

Patterns and Samples can be inspected at the same place on and after 19th inst., between the hours of Ten a.m. and Four p.m. (Saturdays, Ten a.m. to Twelve noon).

Contractors cannot be allowed to tender to supply goods to their own patterns, nor can the Company's patterns be sent away for inspection.

The Directors will not consider any Tender unless furnished on the Company's forms; nor any Tender in which any alteration of the form has been made.

The Tenders to be sent in by post, sealed and endorsed on the envelope, "Tender for Stores, Form No. ——," and addressed to "The Chairman, Broadstone Station, Dublin," so as to reach him on or before Ten a.m. on the 27th inst.

The Directors do not bind themselves to accept the lowest or any Tender.

By Order,
PERCY A. HAY,
Secretary.

Broadstone Station, Dublin,
June, 1922. U 487

THE HIGH COMMISSIONER FOR INDIA is prepared to receive

Tenders for the Supply of:—WROUGHT IRON CYLINDRICAL BUFFERS, &c.

Forms of Tender may be obtained from the Director-General, India Store Department, Belvedere Road, Lambeth, S.E. 1., and Tenders are to be delivered at that Office not later than Two o'clock p.m., on Friday, the 7th July, 1922.

T. RYAN,
Director-General. U 481

APPOINTMENTS OPEN.

UNIVERSITY OF BIRMINGHAM. ASSISTANT LECTURER IN CIVIL ENGINEERING. GRADE II.

Applications are Invited for the POST of ASSISTANT LECTURER in the Civil Engineering Department. Commencing stipend, £400 per annum.

A good University Degree and Practical Experience of Constructional Engineering are essential.

Applications, with testimonials and references should be forwarded to the undersigned not later than July 4th.

Further particulars may be obtained from—
GEO. H. MORLEY, Secretary. U 475

Boilershop Superintendent WANTED, age between 35 and 45. Must have had previous experience in charge of boilermakers and experience of both light and heavy work an advantage. Shop hours. Good prospects for really live man. State experience fully, age and salary expected.—Address, SUPERINTENDENT, WM. POINTON & Co., Advertising Agents, Glasgow. U 470

Steam Efficiency Engineer WANTED for a large Factory in the Argentine. The applicant must have a thorough theoretical and practical knowledge of steam and be conversant with the usual recording and measuring instruments and from the information obtained from these able to work the boiler plant efficiently and economically. One who has held a position where the economical working and scientific control of boilers and steam using apparatus was an objective preferred. Write, stating qualifications and salary asked, giving full particulars of scientific training and practical experience. Age not to exceed 38.—"A.R.T." c/o STREETS, 30, Cornhill, London, E.C. 3. U 401

General Manager Wanted for short Railway in South America (not necessarily an Engineer) not over 45 years of age, energetic, good business man with experience in the organisation and management of traffic. Fluent Spanish essential. Good salary to suitable man.—Write, giving full particulars as to experience, to S. A., c/o STREETS, 30, Cornhill, E.C. 3. U 485

Manager Wanted, for Old- established Company manufacturing Case-hardening and Heat Treating Compounds; must have expert knowledge and experience of manufacturing, and their uses, combined with commercial training. State age, experience, with testimonials and salary.—Address, U 461, Offices of ENGINEERING.

WORKS MANAGER FOR THE NORTH WESTERN RAILWAY CARRIAGE AND WAGON WORKSHOPS IN INDIA.

THE SECRETARY OF STATE FOR INDIA invites—

Applications for an APPOINTMENT as WORKS MANAGER for the Carriage and Wagon Shops of the North Western Railway at Lahore, on a five years' agreement in the first instance, on a salary of Rs. 1000 a month rising by annual increments of Rs. 50 a month to Rs. 1200 a month.

Candidates should be about 36 to 40 years of age. They should have been regularly trained as Mechanical Engineers and have had subsequent experience in Carriage and Wagon work either in a Railway workshop or with a well-known firm of Carriage and Wagon builders. They must be well versed in the construction and maintenance of modern railway rolling stock and possess a good knowledge of modern methods of workshop management. They should have had experience in the production of duplicate parts for the repair and maintenance of rolling stock especially high capacity (all steel) wagons, and should be well acquainted with the latest methods of mass production of carriage and wagon details from modern manufacturing plant and high class automatic machinery. They should also be acquainted with piece work and bonus systems of working.

They must be good organisers, strict disciplinarians, able to control labour and should have held positions of responsibility in either a Railway Carriage and Wagon Workshop or with a contract firm of carriage and wagon builders.

Full particulars regarding the terms and conditions of appointment can be obtained from the SECRETARY, PUBLIC WORKS DEPARTMENT, India Office, Whitehall, S.W. 1, and applications for the appointment, giving full particulars of the candidates' age education, training and experience, should reach him not later than the 18th July next.

India Office, 8th July, 1922. U 469

Chartered Patent Agent, large provincial city, DESIRES ASSISTANT. Must have technical and business qualifications and be able to act as Manager. Salary (commencing) £360–£500 according to qualifications. Applicants should state age and furnish particulars as to education and business experience. Good prospects for suitable man.—Address, U 415, Offices of ENGINEERING.

Mechanical Draughtsman, Ex- perienced, REQUIRED in London; knowledge of oil mill and general layouts, steam, hydraulic, structural and tank work, and calculations.—Applicants to state fully shop and drawing office experience, age and salary required. BOX B 933, LEE & NIGHTINGALE, Advts. Offices, Liverpool. U 464

Wanted, Engineer as Chief Draughtsman; must be a live man able to get production drawings out at lowest possible cost. Experience in the administration and routine of modern Drawing Offices of primary importance.—Apply, with full particulars, stating age and salary, to DRAWING OFFICE SUPERINTENDENT, THE ENGLISH ELECTRIC CO., LTD., Ordnance Works, Coventry. U 390

Sales Engineer Required, to take charge of Plant Sales of large Electrical Engineering Manufacturing Firm in India. First-class experience in heavy plant work and sales experience essential.—Address, U 494, Offices of ENGINEERING.

Wanted, First-class Designer for large furnace work. Must have sound knowledge and practice experience of such work and of refractories.—Apply, ARTHUR DUCKHAM AND CO. (1920) Ltd., 52, Grosvenor Gardens, S.W. 1. U 455

ASSISTANT CHARGE ENGINEER.

Assistant Charge Engineer REQUIRED. Must have thorough mechanical training of at least three years workshop experience. Present commencing salary approximately £386 18s. p.a.; subject to adjustment in accordance with the conditions of employment of technical engineers on the staffs of Electricity Supply Undertakings. Age between 25 and 35 years.—Applications will only be considered on forms to be obtained from the undersigned, which must be returned to the CHIEF ENGINEER, 50, Iden Grove, Holloway, N. 7. U 453

Wanted, Fully Qualified AUTOMOBILE DRAUGHTSMAN. Preference will be given to applications from men who have specialized in Commercial Vehicle Design.—State age, experience and salary expected to Box No. C.M. 340, c/o DAWSON'S, 121, Cannon Street, E.C. 4. U 471

Wanted, temporarily, several JUNIOR DRAUGHTSMEN for details. Must have had experience in locomotive crane work.—Address, stating age, salary required and when can start, U 479, Offices of ENGINEERING.

Foreman Wanted for Dynamo and Motor Construction Department by large firm in Midlands. Must have fair technical as well as thorough practical training and be qualified to take charge of men. State experience, training, age, salary expected, and when available.—Address, U 446, Offices of ENGINEERING.

SITUATIONS WANTED.

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THE DETERIORATION OF MATERIALS USED IN HARBOUR CONSTRUCTION.

SINCE 1916, an important Committee appointed by the Institution of Civil Engineers has been engaged in investigating the causes of deterioration of structures, partly or wholly immersed, in sea water, and in devising measures that would ensure longer life to materials subjected to such conditions. The war necessarily occasioned some delay in the active prosecution of this work, and the first report was not issued till four years later. In that report, to which reference was made in our issue of April 30, 1920, page 584, the problem was very fully stated, the necessity for inquiry was clearly demonstrated, the available mechanism for dealing with it was explained, and the lines of investigation to be followed distinctly detailed. The Committee of the Institution has now published a second (interim) report, which besides showing the progress that has been made, contains a number of abstracts from the proceedings of various committees and associations, English and foreign, indicating the interest the subject has created throughout the world. Various officials have also made reports on matters of particular interest. The full reports will no doubt, in any case, be preserved in the archives of the Institution and be available for those concerned, but it is to be hoped that they will also be published *in extenso*. Not only will the information drawn from so many sources, under very varied conditions, and commented upon by experts, prove very instructive, but the practice of docketing and pigeon-holing reports is very discouraging to original investigation. It is a quite inadequate acknowledgment of the care and trouble spent in collecting and arranging the facts at first hand.

It was with deep regret that his colleagues learned last year that Sir W. Matthews, whose death occurred in January last, felt obliged on account of ill-health to resign the chairmanship of the Committee. The enthusiasm with which he inspired, and the energy with which he directed the proceedings, are gratefully acknowledged in the report under notice. On his resignation Mr. M. F. G. Wilson accepted the chairmanship, and the other vacant seats on the committee, occasioned by death or resignation, have been filled by Sir Cyril R. S. Kirkpatrick, Mr. L. H. Savile, and Professor W. C. Unwin.

The more efficient protection of timber was a subject in which the committee were closely concerned, and the provision of appropriate forms of preservative engaged their attention from the first. Creosote offered the most promising means of effecting an improvenent, and they now report the progress made by experiments, to determine the suitability of creosote and the possibility of rendering the creosote more effective by the addition of poisonous substances. With regard to the first part of the inquiry, the committee report that specimens of timber have been purposely exposed at Accra, Auckland, Brisbane, Colombo, Wellington and Leith, and that from some of these stations have been received specimens of native timber, that had been submitted to tests with the view of determining the maximum load, the modulus of rupture, the modulus of elasticity and total deflection previous to fracture.

Of course it is as yet much too soon to draw conclusions from the systematised experiments proposed by the committee, but at Auckland observations made in timbers exposed to the attack of teredo and other pests have been continued. Some specimens of timber, 42 in. by 3 in. by 1½ in., in an unprotected condition, and others that had been protected by crude creosote and patent protectors, had been exposed in sea water up to May, 1920, but it is not quite clear how long they had been in the water when examined. All, however, were found to have been attacked by the teredo: Kahikatea, severely, Rimu and Kauri, less so, but the Oregon pine had disappeared, having been completely destroyed. Mr. Marchbanks, chief engineer of the Wellington Harbour Board, in sending specimens with description of tests states, "that the timber suitable for harbour work is getting scarce and difficult to obtain in New Zealand, and that the Colony is getting more and more dependent on Australia for supplies. Under these circumstances, it is submitted that the question of the suitability of New Zealand timber for other than limited local requirements is no longer of great importance."

Other reports indicate active co-operation and eagerness to participate in the inquiry, and outside our own Colonies very material assistance is likely to come from the United States. The American Wood Preservers' Association has taken up the subject with vigour, moved to this end by the very serious loss due to the action of marine borers on the harbours of the Pacific Coast. This association has issued a report which shows that a very thorough and systematic investigation will be pursued throughout the whole length of the coast line of the United States. It appears that in past years, since 1870, the attacks in San Francisco Bay have been sporadic and varying in virulence, but in the earlier period little attention was paid to the pest, as it was believed that the quantity of fresh water discharged into the bay from the combined flow of the Sacramento and San Joaquin Rivers would reduce the salinity of the water to such an extent, that it would prove an unfavourable habitat for Teredo and Limnoria. This expectation apparently was not well founded, and with time the depredators have increased. It may be suggested that the enormous quantity of water drawn from the upper reaches and tributaries of these rivers for the purposes of irrigation has diminished the supply of fresh water, and has allowed the salinity at the outfall to increase to such an extent that the breeding of the teredo has been encouraged. Moreover, in recent years the rainfall has been below the normal, and it is in those years that the ravages have been greatest. In 1917, damage to timber piling became evident, and two years later, waterfront structures in the bay erected on piles, began to fall, and in some cases whole docks were effected. Loss and insecurity became so great, that the Wood Preserving Association appointed a committee to study the problem, but this committee did not begin active work till July, 1920. Previous to this date, the United States Forest Service and other agencies had made local investigations concerning the activities of marine borers and the methods for their due control. These scattered associations have now concentrated their efforts in a systematic programme, which has for its object the investigation of the entire problem, including the hydrographic, the biological and the engineering phases. The biological work carried out under the superintendence of Dr. C. A. Kofoid shows that invasions of borers are induced by the shipping traffic, and that preventive measures are an absolute necessity. The port of San Francisco has become the resort of the most widely known and most destructive representatives of the groups to which they belong. To these importations, however, California contributes, on its own account, a pest of special virulence. The Xylotrya is, however, no mean second in the competition, and though it adopts unusual habits of boring they can prove very effectual. Some of the piles in the dolphin of the Alameda Mole, driven in February, 1919, were so weakened at the mud line by the tunnelling of Xylotrya, that they had to be removed in November, 1920. Teredo navalis can accomplish 4 in. penetration in as many months, and is a foe to be respected. Among the crustacean borers is the Limnoria lignorum, a species which acquired considerable notoriety in the last report, and whose ravages are very destructive since they often complete the work of the teredo.

The recommendations submitted to the committee for coping with the destructive work of these organisms seem hardly adequate, but time will be required to determine their efficiency. It is proposed to restrict the uncontrolled use of untreated or unprotected timbers in marine structures, to remove by State or Federal sanction all old, unused, infected marine structures, and to prevent harbours being used as a dumping ground for waste wood. As a protection to piles it is proposed to use bark, metal sheathing, and paints of various kinds. Some forms of concrete protection are described, and among these the Koetitz pile is in favour. This pile is formed by slipping over an untreated wooden pile, a previously made reinforced concrete cylinder and driving the cylinder into the mud, the space between the wood and the concrete being then filled with sand or grout. Some of the suggestions appear rather bizarre, than practical. Among the more fantastic is the proposal to explode dynamite in the water round the piles, in the hope that the concussion would destroy animal life. This plan has been tried by the ingenious, but like the plan of electrolysis of the water, liberating chlorine gas, supposed to be fatal to the teredo, it has proved futile. Another arrangement suggested by the study of the habits of the borer was to construct the pile of separate planks, spiked together, so as to present from any direction the greatest possible number of cracks in order to intercept a continuous path through the pile, the belief being that the shipworm could not cross a crack. But whatever the scruples of the ship worm may be, it soon became apparent that Limnoria had none, and the plan proved to be one adopted to afford shelter rather than discouragement to intruders.

Such experiments show conclusively the need for obtaining more precise knowledge of the life history and habits of the marine borers. The committee early recognised this necessity, and selected Plymouth as a suitable site for experimental work, since the laboratory of the Marine Biological Association would be available. The investigation was entrusted to Dr. G. Barger, and Mr. C. R. Harington, the latter of whom experienced great difficulty in finding either the teredo or the evidence of its work. The reasons assigned for its absence are interesting, as they support the early views of the biologists at San Francisco, where the conformation of the coast line is similar. Mr. Harington ascribes the absence to the variations in salinity due to the inflow of fresh water and interference with the free tidal wash, which in its turn affects the quantity and character of the food supply. At Exmouth, where the docks are far up the estuary, it might be expected that teredo would be absent for the same reason, and this is the case, but at Falmouth, where the inflow of fresh water is slight and the tidal wash unimpeded by a breakwater, teredo are abundant. The observed conditions point to a possible way by which the pest might be eradicated, and the process would be a repetition of that already adopted at Hartlepool, where fresh water is periodically pumped into the timber ponds to preserve the timber intact. Evidently the degree of permissible salinity must be determined experimentally, and unfortunately owing to the want of a proper supply of food, Mr. Harington was not able to bring vigorous cultures of the free-swimming larva to the stage, when they attack wood, but experiments in rearing spawning teredo in water in which the salinity was varied from 35 per cent. to 5 per cent. showed that the lower limit at which the larva could swim with ease was about 20 per cent. A lower percentage would probably suffice under natural conditions where the wash of the tide tended to keep the mollusc alive.

Another possible form of riddance which has engaged the attention of the committee is to impregnate the timber with some poisonous substance. It appears not impossible but that ordinary creosote contains some substances toxic to teredo, but these constituents of creosote are soluble in water, and are therefore soon washed out of the wood. To make the practice successful it is necessary to find some toxic substance soluble in creosote, but insoluble in water. A difficulty is here presented because the toxicity in sea water is difficult to measure, on account of the slight solubility which is essential to the problem. In some experiments with concentrations of 1 : 10,000, the soluble limit of the chemical employed was passed, the substance therefore remained partly in suspension and rendered the test unsatisfactory.

Certain chemicals were found to be decidedly toxic on Saxicava, Mytillus and Limnoria, and to fulfil the conditions of insolubility in water. A substance containing arsenic and used in gas warfare seemed specially suitable, and more poisonous to teredo than the tar acids of creosote. As a crucial test it was proposed to dissolve the poison in boiling creosote and to soak pieces of dried deal in it for three or four days, when a fairly even impregnation to the depth of half-an-inch could be obtained. Impregnation

of harder woods was not attempted in this preliminary inquiry. The prepared pieces of timber with others treated with creosote, and also untreated timber, were exposed in suitable localities and examined last Christmas, but only the untreated controls were attacked slightly by limnoria. Either the specimens were not exposed long enough or they were put out too late in the season. The experiments will be continued next year. It is not impossible, as some of the experiments seem to show, that the boring organisms possess different degrees of immunity to poisons and of indifference to creosote. In a piece of creosoted timber from which the preservative had been washed out, it was noticed that while the attacks of limnoria were confined to that part of the wood free from creosote, the burrows of teredo penetrated into every part with apparent impartiality.

In the first report issued by the Committee it was shown that the denser and more resisting kinds of timber, which, like greenheart, resist teredo attack, with great success are very difficult to impregnate, and Dr. Barger is continuing experiments to determine the best method of injecting poisons in such cases. Some of his prepared specimens are being exposed at Lowestoft, where the water is very much infested with various pests. Steps, too, are being taken to send similar specimens to tropical parts where the boring effects are more rapid and more destructive. It must be remembered, however, that in any case, the toxic effect of the prepared materials cannot be expected till the unpoisoned creosote controls have been attacked. With regard to greenheart, of whose endurance many instances were given in the last report, Dr. Barger, with the view of determining whether the immunity was due to its texture or its chemical composition, has had a considerable quantity of greenheart sawdust extracted by alcohol, by chloroform, and by dilute ammonia. It was found that the alcoholic extract contained an alkaloid corresponding to bebeerine, previously found in the bark, and it is proposed to have test pieces of timber impregnated with alcoholic solutions of the alkaloid, and other constituents, and also with synthetic chemicals in suitable solvents, other than creosote. The intention is to trace the action of the alkaloid upon the larval and adult teredo, with the view of ascertaining if the timber in question can by this means be rendered immune from attack.

With regard to the power of concrete to resist the action of waves, frost, and marine organisms the committee add reports on the deterioration of structures exposed to sea action. Mr. L. H. Savile treats the subject generally from the Admiralty point of view, and Mr. T. B. Hunt and Mr. G. P. Hayes deal in detail with the harbours of Portsmouth and Devonport, respectively. At those places the materials have long been exposed to sea action, and the experience gained is sufficient to enable some practical conclusions to be drawn, so far as Admiralty works are concerned. Mr. Savile insists upon the necessity of rendering the concrete impenetrable by sea water, for the percolation through the interstices will inevitably lead to destruction.

The action of the weather above high water level is also particularly noticeable in ferro-concrete structures. The vast majority of rust spots occur in this position, and particularly on the under side of beams where, through faulty workmanship, the stirrup has dropped in the mould during concreting. The Admiralty is emphatically of opinion, that in exposed positions the least cover for reinforcement should not be less than 1½ in., and preferably 2 in., in order to allow for those practical exigencies which are inseparable from normal experience. The pounding action of the waves cannot be avoided, and good workmanship is usually sufficient protection, but the thrash of wave-borne shingle and sand may cause deterioration, against which it is difficult to provide an adequate remedy. It is suggested that since air-dried concrete is the stronger and more reliable form, a desirable course of construction would be to prepare concrete in mass, or blocks, on land and transport these to the site. In a more detailed report on Devonport Dockyard, Mr. Hayes states that ferro-concrete has been satisfactory, and has withstood the action of sea organisms where the matrix has been of good quality and homogeneous throughout; but where the cement has been insufficient deterioration is rapid. Instances are given to show that piles erected sixteen years ago exhibit no signs of wear, and when the surface is broken by abrasion the interior is clean and hard, with externally very few rust spots. On the other hand, a landing pier constructed of ferro-concrete in 1911 shows extensive signs of deterioration, owing to the mixing not having been continuous throughout. Fairly large pieces of the surface have broken away, exposing a very soft interior, the grains of quartz being quite free of any mortar. Further, there are many rust spots.

These reports show generally that the materials are apt to be better than the workmanship, and it is doubtful if the best results have yet been secured. This conclusion is supported by reports from the Bureau of Standards of the United States Department of Commerce, dealing with the structures of the Navy Yards of Boston and Puget Sound. The aim of these reports is to show how trouble can be avoided, and to ensure the production of more durable work. One point insisted upon in an emphatic manner is the rapid deterioration caused by the use of too little, or too much, water in mixing the ingredients. Attention is also directed to the chemical disintegration of concrete both in hot and cold climates, and the need for radical modification in the design of reinforced concrete work in marine structures.

One great difficulty in completing these experiments is the length of time necessary for the completion of adequate tests under natural conditions, but at Boston where the variations of exposure are very severe, an experiment on the effect of varying the amount of water in concrete has been unintentionally carried out. In one of the piers, concrete of three different consistencies has been accidently employed, and the conditions of that section of the structure where the cement and aggregate have been mixed with a medium amount of water are decidedly superior to the remainder. What other conditions may have obtained since erection are not known, but experiments are still being carried on at Boston by a private company, on a large scale. Mr. Bakenhus reports the results of a seven years' test of 24 concrete specimens, each 16 ft. in length and 16 in. square, cast horizontally and suspended vertically. Each weighs from 4,050 lb. to 4,350 lb., and is moored in such a way that the lower end is continually immersed in the sea, the upper end occasionally, and the central portion is subject to the alternate action of air and salt water. The composition and mixing are varied, the object being to test the effect of wet and dry mixtures, rich and lean mixtures, the use of special brands of cement, admixture with hydrated lime, addition of patents, &c. The monoliths are examined at intervals of a year, and the following conclusions have been accepted by experts. That the use of sea water in mixing is not injurious. That the substitution of 10 per cent. of hydrated lime for an equal quantity of cement favoured an earlier and more rapid erosion. That the addition of soft soap and powdered alum (a recommended patent) was decidedly harmful, and that 5 per cent. of clay added to the cement exercised a beneficial effect on the concrete.

The third material upon which the committee proposed to experiment was steel; and Sir Robert Hadfield reports that the preparation of the whole of the specimens intended for exposure at the various stations has been completed, and some of the consignments have been despatched. Dr. J. Newton Friend has made himself responsible for the weighing, marking and identification of the various bars. The specimens are divided into four sections, I, Irons (rolled and forged); II, carbon steels with varying percentages of manganese, sulphur and phosphorus; III, special steels including a 13·50 per cent. chromium steel ("non-rusting" steel); and IV, hot and cold blast cast-iron. About 80 bars of dimensions 24 in. by 3 in. by ½ in. of each material have been prepared, a total in all of 1,330 bars.*

* A very valuable and interesting paper entitled "The Preparation of the Various Ferrous Metals used in the Corrosion Research of the Institution of Civil Engineers together with their Physical and Mechanical Properties and some General Consideration on the Subject of Corrosion," by Sir Robert A. Hadfield, was read before the Institution of Civil Engineers on April 4 last. An abstract of this paper appeared in our issue of April 7 last, page 419 *ante*.

SOCIÉTÉ DES TRANSPORTS EN COMMUN DE LA RÉGION PARISIENNE.

THE company which forms the subject of the present brief description, and whose name is given in the title, is one which has the entire charge of the combined passenger tramway and motorbus service both throughout Paris and in the suburbs in direct connection with the metropolis. The origin of the concern dates back to the year 1828, when the Entreprise Générale des Omnibus placed in the service passenger traffic accommodation, with the comparatively very poor vehicles then available; the success it met with, however, soon led to the formation of a number of competing companies. In course of time there were as many as 10 such companies, and these, in the year 1855, combined together to form the Compagnie Générale des Omnibus. The first concession for horse-tramways dates from 1854; it was granted to a Mr. Loubat, and was retroceded two years later to the latter named company. From 1870 to 1900, numerous other tramway concessions were granted, without any order or method, to different companies some of which were of but indifferent standing; a number of the lines thus conceded were never built. A first attempt at the reorganisation of the tramways was made in the year 1910. The number of the concessionaire companies was decreased from 13 to 9, by the combining of several among them and the granting of new concessions.

Mechanical traction was resorted to for the first time in 1889 by the Compagnie Générale des Omnibus, by means of Rowan steam-driven cars, and by the Compagnie des Tramways de Paris et du Département de la Seine (North Paris Tramways) by means of Francq superheated steam cars. Both these types had been tested satisfactorily a few years before the above date. The latter company placed in its service in 1893 the first cars equipped with slow charging storage batteries, and in 1897 the first cars equipped with rapid charging ones. Traction by compressed air was adopted in 1895 by the Compagnie Générale des Omnibus, then by another company (Paris-Arpajon), but the first trials with compressed air traction dated back to 1876. In 1896 a line (Romainville) east of Paris, was equipped for electric traction on the Claret-Vuilleumier surface-contact system. Electric traction both on the trolley and conduit systems dates from 1900, the year of the Paris Exhibition; one or the other of these two systems was fitted to a few lines of the Compagnie Générale Parisienne de Tramways (South Paris Tramways), to new lines (West, East and North Paris Tramways, and left bank tramways) and on a part of the Arpajon line above referred to. In 1910, it was decided to do away entirely with horse traction and also with electric traction by storage batteries, and shortly before the great war by far the greater part of the tramway lines were equipped for electric traction by either the trolley or the conduit system.

The horse-drawn omnibuses were gradually replaced by petrol driven ones, and from the year 1913 the former ceased to be used.

At the outbreak of the great war the various systems were as follows:—

Compagnie Générale des Omnibus de Paris:—

43 omnibus lines.
33 tramway lines having a total length of 289,830 m. (180 miles), of which 207,600 m. (129 miles) were on the trolley system, and 82,230 m. (51 miles) on the conduit system.

Tramways Nord:—

43 lines, 281,630 m. (175 miles) in total length, of which 259,865 m. (162 miles) were on the trolley system and 21,765 m. (13 miles) on the conduit system.

Tramways Sud:—

13 lines, 137,736 m. (85 miles) in total length, of which 97,409 m. (60 miles) were on the trolley system and 40,327 m. (25 miles) on the conduit system.

East Paris :—

13 lines, 146,418 m. (91 miles) in total length, of which 141,759 m. (88 miles) were on the trolley system and 4,659 m. (3 miles) on the conduit system.

Nogent lines :—

10 lines, 44,661 m. (27 miles) in total length, on the trolley system.

Left Bank Tramways :—

5 lines, 42,406 m. (26 miles) in total length, on the trolley system.

There were, therefore, in all, 43 lines of omnibuses and 117 tramway lines, of which latter 492 miles were equipped for traction by trolley and 92 miles for traction on the conduit system.

During the war the difficulties encountered in the operation of all these omnibus and tramway lines can well be imagined.

After the war, matters were complicated by the fact that there were six principal concerns, those enumerated above, each of which was tied down by a system of rigid concessions which greatly handicapped a suitable development of the passenger traffic. Thereupon, the Paris municipality and the representatives of the surrounding suburbs decided together to combine the main services into one single concern, the Société des Transports en Commun de la Région Parisienne, which now operates 127 tramway lines having a total developed length of 1,025 km. (637 miles) and 41 omnibus lines serving a total length of 256 km. (159 miles) in both instances within the metropolis and extended to the adjoining suburbs.

Current for working the tramways is supplied by the Paris generating stations, in the form of three-phase current at a pressure of 10,000 or 13,500 volts, as the case may be, to sub-stations which convert it into 600-volt continuous current. The company has at its disposal 16 sub-stations for a total of 34,500 k.v.a. There are, further, 16 other sub-stations having an equipment for a total of 27,500 k.v.a. The rating of the converter sets in the sub-stations varies from 500 kw. to 2,000 kw., and in every sub-station space is available for the accommodation of one or two extra similar sets. Any sub-station can be supplied by any of the three generating stations. Pressure balancing transformers enable the interconnection of the system notwithstanding the difference in the pressure of the three generating stations. The high-tension mains are all most carefully insulated, and according to the system generally followed in Paris they are generally at a depth of 1·3 m. (50 in.) under the street level, and entirely surrounded by sand, there being the usual protecting devices. At some parts they are laid inside cast-iron pipes, or earthenware pipes.

All the sub-stations are equipped on the same general plan. They contain a high-tension switchboard, transformers which lower the pressure to 380 volts, converter sets and a low-tension switchboard. Each has two sets of high-tension busbars, which allow the simultaneous delivery to the sub-station of the current from two generating stations, without involving the need of putting these latter in parallel. There are, further, two sets of low-tension busbars, which enable two independent low tension supplies to be furnished simultaneously.

There is nothing special to be mentioned with regard to either the positive or negative feeder system. It may be stated, however, that the overhead trolley lines are gradually being replaced by conduits.

The low-tension feeders are mostly of aluminium, carefully armoured, also laid in sand, and provided with protecting devices.

In the same trenches with the high and low-tension cables are auxiliary cables to fully insure all electric connections. These also enable communication by telephone between every section of the line and the various stations, and further act as pilot leads to indicate any defect in insulation or irregularity of voltage on suitable instruments at the sub-station.

We need not enlarge upon the trolley-wire suspension system. In the centre of Paris, traction is on the conduit system, the conduit having two steel current supply rails, each one supported separately on insulators. The sliding contact is bi-polar. The track and conduit rails are fitted to cast-iron chairs placed 1·3 m. (50 in.) apart.

Fig. 1.

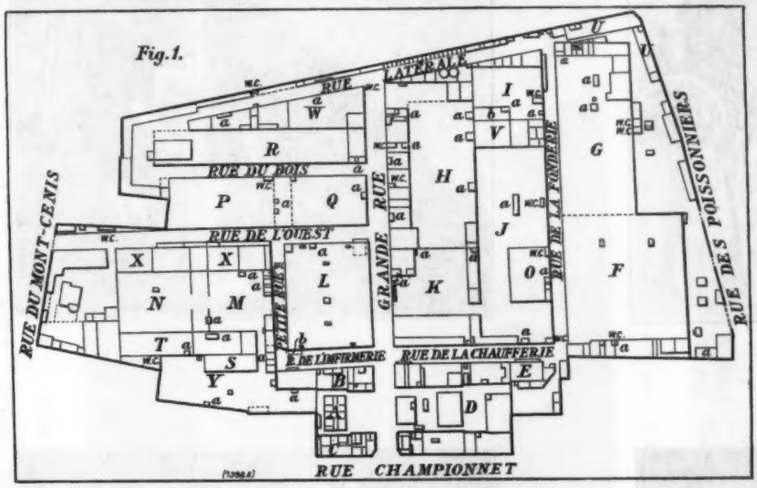


FIG. 1. PLAN OF WORKS, RUE CHAMPIONNET.

There are several types of tramway cars. For example, the hauling car of the G type has a wheel-base of 3·6 m. (8 ft. 11 in.), it carries 49 passengers and weighs empty 14,800 k.; it is propelled by two 600-volt motors of 50 h.p. each, having auxiliary commutating poles. The body is 10·65 m. (34 ft. 9 in.) in length, there being a central platform, the floor of which is lower than that of the two end compartments. The hauling car of the B type carries 54 passengers, has a body 11·986 m. (39 ft. 4 in.) in length and weighs empty 16,400 k. It is generally similar to the G type, and its equipment consists of two 600-volt motors of 60 h.p. each. The hauling car type 500 weighs empty 18,900 k., has a length of 12·020 m. (39 ft. 6 in.) inside buffers, carries 56 passengers and is also equipped with two 600-volt motors. There are other types of hauling cars, also trailing cars, 11·606 m. (38 ft. 3 in.) in length, carrying 81 passengers weighing empty 8,400 k. The company is actively engaged at the present time in the introduction of a uniform type of rolling-stock over the whole system. The service is insured by 1,764 hauling tramway cars and 779 trailing cars, and the company has planned the construction of 350 and 200 cars respectively, between now and the end of 1923. All the tramway cars are single-decked.

The motor 'buses also are all single-decked vehicles, of which there are now 1,050 to which 200 others will be added by the end of 1923. They are all of the same type, having a rear platform, the 'bus carrying 38 passengers. It is propelled by a four-stroke cycle 34-h.p. engine, running at 1,000 r.p.m., taking petrol, benzole, or a mixture of 50 per cent. benzole and 50 per cent. alcohol. This is a four-wheel vehicle. A six-wheel car, weighing empty 7,350 k., and 10·429 m. (34 ft. 3 in.) in length, to carry 48 passengers, is designed for the Madeleine-Bastille service, the heaviest omnibus service of the company. This is to be propelled by the same engine as above. Trials are being carried out with a trolley omnibus. All the omnibuses are inspected after an average total run over 50,000 km. (about 31,000 miles) corresponding to a service of about 15 months.

The Metropolitan Railway belongs to other companies, but the Société des Transports en Commun has had charge of renovating and working the steamboats which ply upon the Seine, a service which ceased during the war. The boats have a length of 33·25 m. (about 110 ft.), a beam of 5·04 m. (16 ft. 6 in.), they carry each 400 passengers, have a displacement of 70 tons loaded, a draught of 2·30 m. (7 ft. 6½ in.), and the speed is roughly 10 statute miles per hour.

The company works the tramways, the omnibuses and the Seine steamers above referred to. Its revenue consists of the receipts proceeding from the passenger traffic, and whilst practically an independent company, it is under the direct jurisdiction of the Paris municipality, which acts in combination with the representatives of the different suburbs that are also served. The company has a total staff of over 24,000. During the year 1921, the first year of its working as a corporate body, it carried 860,000,000 passengers.

The main works for the construction of both tramway cars and motor omnibuses are situated in the Rue Championnet, north of Paris. Their arrangement is shown in the plan, Fig. 1, the references being as follow :—

A. Main offices.
B. Accountants; draughtsmen.
C. Clothes lockers.
D. Central stores.
E. Boiler-house.
F. Garage.
G. Repair workshop.
H. Mechanical workshop.
I. Smithies and heat treatment.
J. Tramway chassis shop.
K. Tramway car erecting and painting shop.
L. Paint shop — omnibuses.
M. Chassis frame shop.
N. Chassis erecting.
O. Electricity shop.
P. Bodywork.
Q. Wood-working machinery.
R. Timber stores.
S. Motor testing.
T. Storehouse.
U. Foundry—iron, brass, aluminium.
V. Tramcar wheel and tyre shop.
W. Omnibus rubber tyre shop.
X. Plate shop and smithy.
Y. Omnibus erecting.
a. Shop offices.
b. Fire pumps.

Views in several of these shops are reproduced in our illustrations, Figs. 2 to 5 on page 742, Figs. 6 and 7 on page 743, and Figs. 8 and 10 on page 744. The site has an area of about 84,000 sq. metres, of which about 56,000 square metres are covered by the shops and buildings.

In the shop marked K, in the centre of the works, the tramway cars are assembled and are fitted with all their mechanical and electrical component parts; they are next wheeled into an adjacent building in which they are painted and dried, a separate shop being provided for the mixing of the various paints used. The various electric apparatus, motors, air compressors for the brakes, resistances, &c., which are received from outside firms, are inspected and tested separately before they are incorporated in the cars. This shop also serves for re-winding the electric machines taken from cars which enter the works for repairs after they have undergone a period of service, when such repairs are necessary, and for this purpose it is equipped with all necessary plant. In the neighbouring shop J are built the new tramway-car chassis frames, these being complete in themselves; from this shop, the chassis frames are sent to the body shop for fitting the wood body frames and the aluminium sheet body sides. The shop J is served by a 12-ton overhead electric travelling crane, and has five transversal tracks, in each of which there is an erecting pit. When the chassis are provided with their bodies, they return so far completed to this shop for mounting upon their bogies. The transversal tracks in question end in a cross-bay that runs over the whole width of the shop and has a traverser which serves both the department for new tramway cars and an adjoining department in which cars are

THE WORKS OF THE SOCIÉTÉ DES TRANSPORTS EN COMMUN, PARIS.

(*For Description, see Page* 740.)

FIG. 2. TRAMWAY WHEEL, TYRE, AND AXLE SHOP.

FIG. 3. OMNIBUS CHASSIS ERECTING SHOP.

FIG. 4. VIEW IN JOINERS' SHOP.

FIG. 5. OMNIBUS PAINTING SHOP.

THE WORKS OF THE SOCIÉTÉ DES TRANSPORTS EN COMMUN, PARIS.

(*For Description, see Page* 740.)

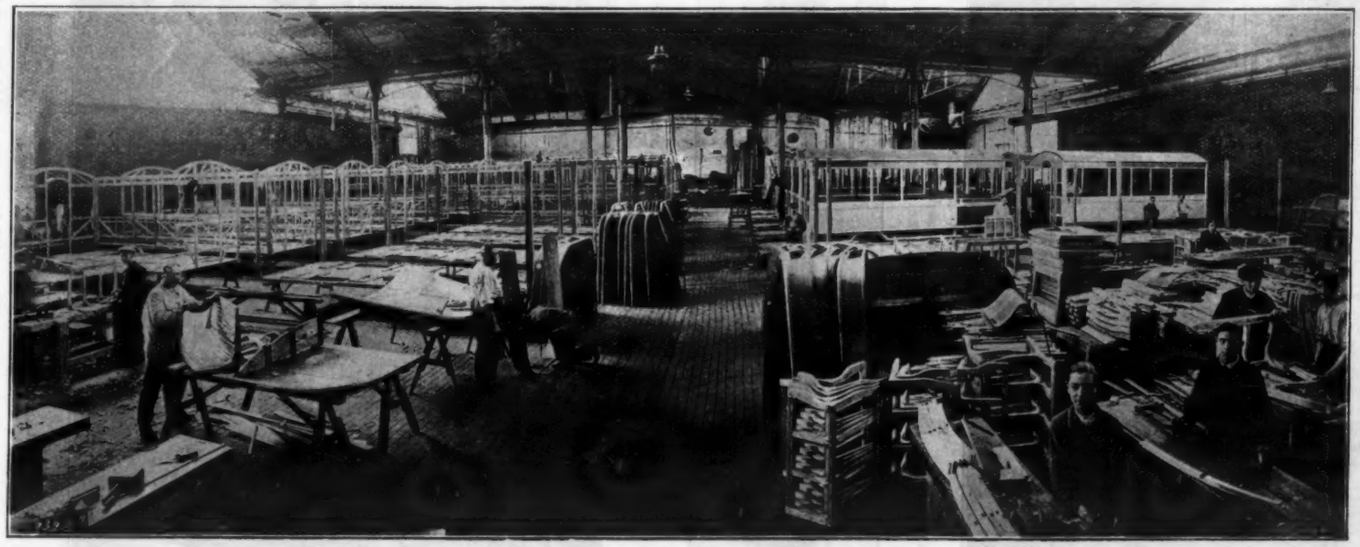


FIG. 6. SHOP FOR ERECTING THE BODY FRAMES FOR OMNIBUSES.

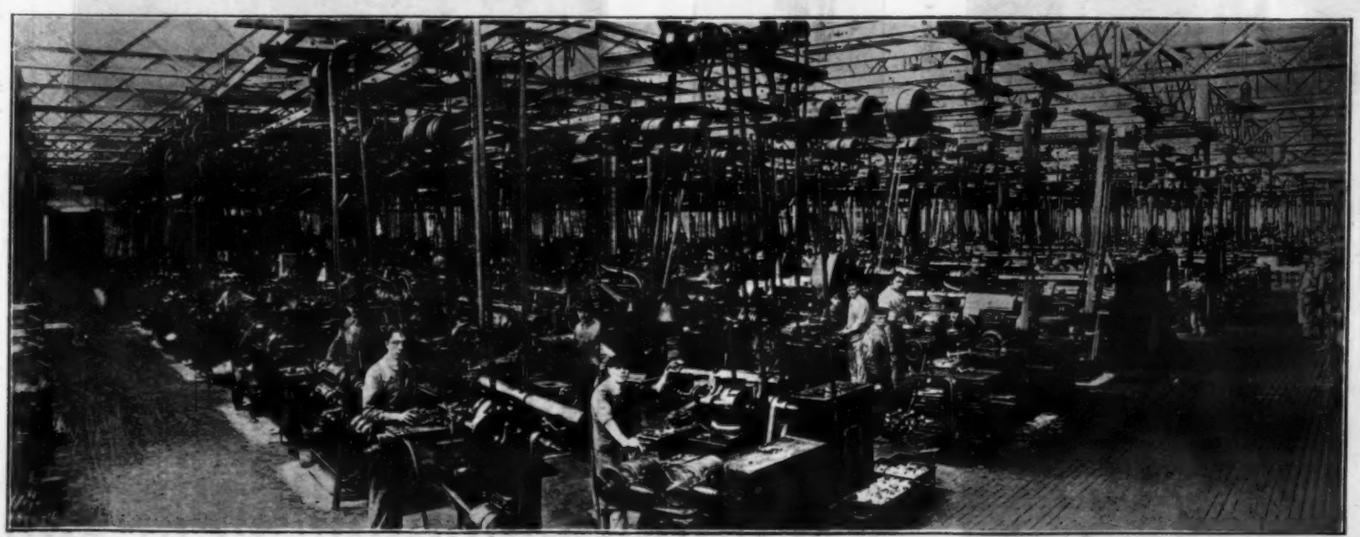


FIG. 7. VIEW IN A MACHINE SHOP.

THE WORKS OF THE SOCIÉTÉ DES TRANSPORTS EN COMMUN, PARIS.

FIG. 8. TRAMWAY CAR ERECTING AND REPAIR SHOPS.

repaired; this is also served by a 12-ton overhead travelling crane.

In a line with the J shops is the V shop in which the wheels and axles are machined and the tyres shrunk on. This is served by a 4-ton overhead electric crane. The view, Fig. 2, on page 742, shows the wheel, tyre and axle shop of the tramway car department.

In the shop marked H are machined all the mechanical parts and fittings for both tram cars and motor 'buses, motor-'bus crankshafts, engine casings, engine cylinders, &c., the machine tools being driven by overhead transmission and by separate electric motors. The forge in which the springs and other pieces are manufactured is marked I. The spring leaves are bent, after heating the bar in furnaces fired with producer gas, in small bending rolls in the centre of the shop. When the laminated springs are assembled, they are tested individually in a testing machine operated by compressed air. The work done in this shop also includes the manufacture of special springs. The equipment further comprises three steam hammers of 2,000 kg., 1,700 kg. and 900 kg. respectively, supplied with steam from the power station, and several flexible-belt stamps, served by gas-fired furnaces or open fires, according to the size of the forging.

The foundry casts small parts of cast-iron (such as brake-shoes, &c.), of brass (journal bearings, trolley heads) and of aluminium (engine casings, &c.). The departments marked G and F are a repair workshop and a depot for the motor omnibuses which are in service in the districts neighbouring the works. The motor 'buses enter this depot every night on completing their daily runs, they are there cleaned and made ready for their service on the following day.

The omnibus chassis erecting shop is shown in Fig. 3, on page 742, Figs. 4 and 5 on the same page being views in the joiner's shop and the omnibus painting shop. The omnibus wood-body frame shop is shown in Fig. 6, on page 742, Fig. 7 on page 743 being a view in a machine shop.

The works have a coal depot at the St. Ouen railway station, whence the coal wagons are hauled to the works by one of their traction engines, or in the works' lorries.

The rubber tyre depot and shop in which the rubber tyres are pressed upon the motor-'bus wheels are shown in the view Fig. 10, annexed; the rubber tyre presses number 4; they are operated by 4 hydraulic pumps, connected to 3 hydraulic accumulators. In the same department is the motor-'bus wheel shop; in this the wood wheels

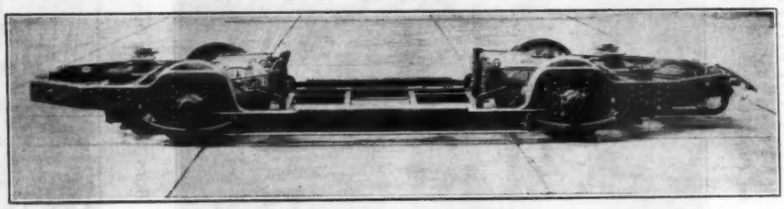


FIG. 9. CHASSIS OF A G TYPE TRAMWAY CAR.

FIG. 10. OMNIBUS RUBBER TYRE SHOP.

are built up, also the band brakes, fenders, &c. This shop is in close proximity to the timber stores R, which measure 128 m. (420 ft.) in length, 24 m. (80 ft.) in width, and contains an assortment of different kinds of timber and a 4-ton overhead electric travelling crane.

The shops P and Q containing the joinery and the tramway car and motor-'bus wood body frame department form one and the same shop, measuring 130 m. (427 ft.) by 35 m. (115 ft.); at the entrance are sawing, planing and other wood-working machines, equipped with suction apparatus for freeing the shop of dust and wood shavings. The machines are separately driven by electric motors located in underground compartments. These shops are shown in Figs. 4 and 6, on pages 742 and 743. The mounted chassis are received at the shop marked P, where they are fitted with their wood body

framework, on which is applied the sheet-aluminium outside body covering. The guard at the rear end and that in front of the driver is of sheet steel. The roofs are of wood covered by tarred canvas. The inside body lining consists of sheets of three-ply wood. When the carriage bodies are thus finished complete, with seats, doors, &c., and fitted to their frame, they are wheeled on shop bogies to the shop first mentioned, the shop marked K on the plan, where they are mounted on their service bogies, painted and finished. Fig. 8, on page 744, shows the tramway car erecting and repair shop, whilst Fig. 9, on the same page, illustrates a chassis of the G type tramway car.

The other shops in the works are those for the body building of new motor 'buses, and for the maintenance and repair of those in service. When these latter enter the works, the body is lifted off in one piece, for inspection and repair in the body shops, the chassis being seen to in the mechanical shops. At M, in plan Fig. 1, is the plate shop, in which all plates are sheared and worked up; welding is effected by the oxy-acetylene blowpipe.

Various other shops in the works are set apart for motor tests, overhauling, coppersmith work, assembling of the motor-'bus parts, &c.

The necessary current throughout the works is supplied by a private distribution company.

At the works in question, the operatives number 2,500, this number being included in the 24,000 above-mentioned. They work from 7 to 11 a.m., and from 1.30 to 4.30, these hours having been determined by the Paris and suburban authorities already referred to, and the men have 21 days holiday every year at their full pay.

The company have further at their disposal 35 depots throughout Paris and the suburbs in which the cars are garaged every night.

THE EFFICIENCY OF THE HAMMER BLOW, AND ITS EFFECTS WITH REFERENCE TO PILING.

By A. HILEY, M.I.N.A., Assoc.M.Inst.C.E.

(*Concluded from page* 714.)

CONSIDERATIONS GOVERNING EFFICIENCY WHEN USING EXTRACTOR HAMMERS.

IF we assume for the sake of convenience that the type of hammer already dealt with is fitted with a pair of steel links making connections to the tube in such a way as to enable the pile tube, already driven to "refusal," to be extracted by this means, there will be two items under elastic stress to consider.

Any resistance due to friction opposing withdrawal of the tube will be regarded as a tensile force acting at the lower extremity of it. The tube thus being put into a state of tension by the extractor blow will absorb energy unprofitably in a similar way to that considered for the driving. The second item playing a similar role occurs at the link connections, which require to be made of material with a high value of E, such as is obtained by the use of solid steel, in preference to extensible ropes.

The loss of efficiency resulting from the action of these items is given by the formula

$$\frac{1}{W\,h}\,\frac{R^2}{2}\left(\frac{l}{E\,A}+\frac{l_1}{E\,A_1}\right)$$

in which W = weight of hammer (tons).
h = height of fall in inches equivalent to velocity of impact.
R = resistance acting at lower end of tube (tons).
l = length of tube, in inches.
E = coefficient of elasticity for steel, 13,000 tons per square inch.

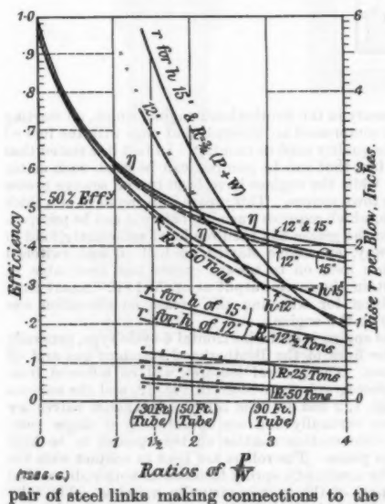


Fig. 9. CURVES OF EFFICIENCIES ON BASE OF P/W. PLOTTED FOR RESIST R OF 0, 25 & 50 TONS & EQUIV. HEIGHTS OF FALL h OF 12" & 15". ALSO PARTICULAR APPLICATION SHOWING RISE r" OF PILE PER BLOW OF EXTRACTOR. PLOTTED FOR 2 TON HAMMER HAVING A STROKE OF 15" & 12" GIVING A VELOCITY OF IMPACT V=9 & 8 FT. PER SEC. RESPECTIVELY.

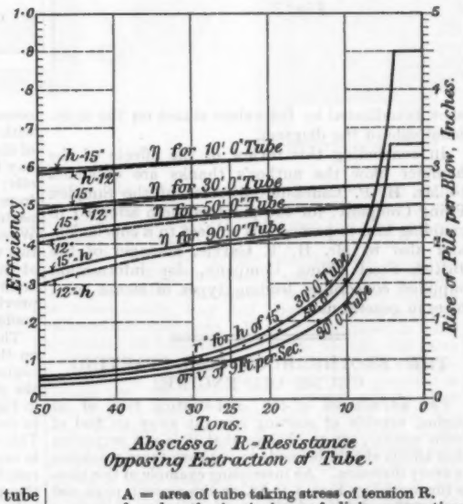


Fig. 10. CROSS CURVES OF EFFICIENCIES ON BASE OF R. PLOTTED FOR TUBES, 10 FT. 30 FT. 50 FT. & 90 FT. LONG & EQUIV. HEIGHTS OF FALL h OF 12" & 15". ALSO SHOWING RISE r" OF PILE PER BLOW OF EXTRACTOR. PLOTTED FOR 2 TON HAMMER HAVING A STROKE OF 15" GIVING A VELOCITY OF IMPACT OF 9 FT. PER SEC.

Abscissa R-Resistance Opposing Extraction of Tube.

A = area of tube taking stress of tension R.
l_1 = length in inches, of link connections between hammer and tube.
A_1 = area of links transmitting tensile stress.

In the case of a 30-ft. tube of 16 in. diameter by ¾ in. thick working against a resistance of 50 tons, when a 2-ton hammer acts through 12 in., the loss of efficiency is

$$\frac{1}{2\times 12}\cdot\frac{2{,}500}{2}\left(\frac{360''}{13{,}000\times 36}+\frac{120''}{13{,}000\times 20}\right)$$

= 0·041 for tube + 0·024 for links

From these values others can be tabulated for different resistances, lengths of tube and stroke of hammer, as given in Table IX.

The efficiencies of hammer blow are given in Table X for various ratios of $\frac{P}{W}$, a coefficient $\lambda = 0{\cdot}5$ being used for coefficient of restitution of steel on brass.

As P represents the entire weight set in motion by a blow from W, after allowing for the burden of piston rod, links, pile cap and head casting, there remains, when considering the case where a 2-ton hammer is employed, a length of tube of approximately 10 ft. for ratio of $\frac{P}{W}$ of 1 and tubes of 30 ft. and 50 ft. for ratios of 1½ and 2 respectively. These lengths are assumed in the table of overall efficiencies.

TABLE IX.—SHOWING OVERALL EFFICIENCIES OF EXTRACTOR HAMMERS.

Length of Tube.	Ratios of $\frac{P}{W}$	η_b	h	R = 50 Tons. Correction for Links η_1	R = 50 Tons. Correction for Tube η_2	R = 50 Tons. Overall $\eta_b - \eta_1 - \eta_2$	for R = 25 Tons. η	for R = 0. η
ft.			in.					
10	1	0·625	12	0·024	0·014	0·587	0·615	0·625
			15	0·019	0·011	0·595	0·618	0·625
30	1½	0·551	12	0·024	0·042	0·485	0·535	0·551
			15	0·019	0·033	0·499	0·538	0·551
50	2	0·50	12	0·024	0·070	0·406	0·477	0·50
			15	0·019	0·055	0·426	0·482	0·50
90	3	0·44	12	0·024	0·126	0·290	0·403	0·44
			15	0·019	0·099	0·322	0·410	0·44

TABLE XI.—EFFECTIVE RISE OF TUBE DUE TO EXTRACTOR BLOWS.

Length of Tube.	$\frac{P}{W}$	A.	W A.	For R = 50 Tons. η W A.	For R = 50 Tons. r Rise.	For R = 25 Tons. η W A.	For R = 25 Tons. r Rise.	For R = ¾ (P+W) η W A.	For R = ¾ (P+W) r Rise.
ft.		in.	in./tons.	in./tons.	in.		in.		in.
30	1½	12	24	11·6	0·23	12·8	0·51	13·2	3·5
		15	30	15·0	0·30	16·1	0·64	16·6	4·5
50	2	12	24	9·7	0·20	11·4	0·45	12·0	2·6
		15	30	12·8	0·25	14·4	0·57	15·0	3·3
90	3	12	24	7·0	0·14	9·6	0·38	10·6	1·4
		15	30	9·6	0·20	12·2	0·50	13·2	1·75

TABLE X.—*Efficiency of Extractor Blow as delivered on a Steel Anvil, faced with Pad of Brass or Ductile Iron.*

Tabulated for ratios of $\frac{P}{W}$ up to 2 and $\lambda = 0{\cdot}5$.

Ratios of $\frac{P}{W}$	Ratios of $\frac{W}{P}$	Energy of Hammer, W h.	Factors for Impact. $\frac{1}{1+\frac{P}{W}}+\frac{\lambda^2}{1+\frac{W}{P}}$	Efficiency of Blow on Anvil, $= \eta_b$
1	1	1	0·5 + 0·125	0·625
1½	⅔	1	0·4 + 0·151	0·551
2	½	1	0·333 + 0·167	0·500
3	⅓	1	0·25 + 0·190	0·440

Extractor blow efficiencies as applicable to tubular piles of the particulars mentioned are given in Table IX for R = 50 tons, 25 tons and zero.

Experience in the withdrawal of preparatory tubular piles, which have in the first place been driven to a firm "set," invariably shows that quite considerable resistances have to be contended with at first, due to the highly compressed earth again closing in and pressing on the exterior of the tube. The resistance is aggravated if, as sometimes happens, the tube has deviated in its course slightly to one side.

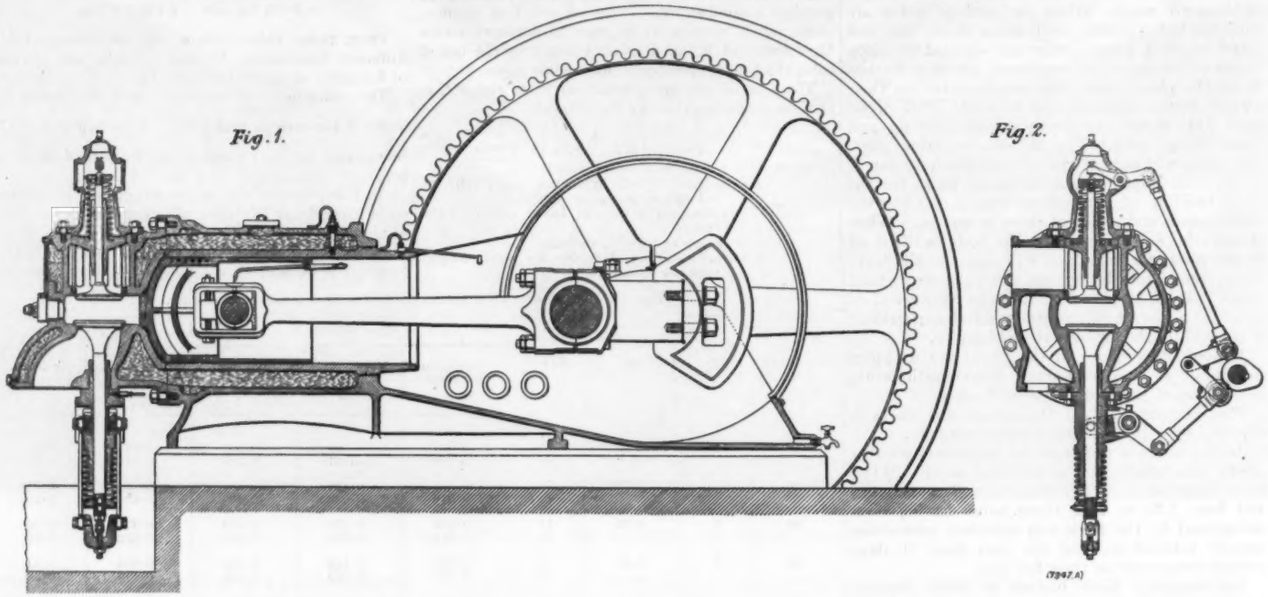
During the extracting, a moderate pull will be supposed to be kept maintained on the tube by suitable tackles.

Allowing for the winch pull of $\frac{P+W}{2}$ the average net resistances for the cases given in Table XI will be taken as 50, 25 and ¾ (P + W), assuming a minimum winch pull.

Fig. 9 shows the curves of efficiencies for an

COLD-STARTING CRUDE OIL ENGINE.

CONSTRUCTED BY MESSRS. PETER BROTHERHOOD, LIMITED, ENGINEERS, PETERBOROUGH.



extractor hammer of characteristics stated above, and the rise of the pile per blow has been indicated for the several resistances assumed.

Fig. 10 shows the cross curves of the same efficiencies as plotted on an abscissa of tons resistance, and also indicates the rise per blow which would be obtained for any of the sizes of pile-tubes stated when these are being extracted against any given resistance.

In order that this investigation may also be of service to engineers whose experience is more closely associated with parallel-sided piles of uniform section which have to be taken to a site and then hammered into the ground, the author ventures to hope that the trellis diagram, Fig. 7 on page 713 *ante*—which contains the essence of his research—may also prove useful to them.

With the data given thereon, it will be found in practice unnecessary to trouble about anything beyond the measurement of the permanent set, as the other element of temporary set has been adequately taken account of in the preparation of the diagram itself, so that the required measurement of the permanent set per blow remains the simple matter as hitherto.

Accordingly, for convenience, the corrections necessary to make the diagram apply to:—

(1) Pre-cast reinforced concrete piles fitted with helmet and cap for driving,
(2) Concrete piles not thus fitted with protection in driving,
(3) Timber piles of approximately parallel form (the full angle of point being for these cases assumed to be about 40 deg.),

have been indicated in the notes attached to the trellis diagram for reference when required.

It should be borne in mind when finding the resistance to driving for the above-mentioned cases, the resistance R figured in tons on the left-hand side of the diagram corresponds solely with an area of pile shoe equal to 240 sq. in. If the projected area of a pile point or shoe be other than this amount, the figured values given for R (which for our purpose is equivalent to $R + rf$ for the driven piles) requires to be modified in proportion to the actual area of the pile shoe for a given case. The result, corresponding to a given quantitative value of $\frac{P}{W}$. h, and the set s, as measured in a particular instance, will then represent the driving resistance overcome by the pile; and this resistance will accord with the product of the actual projected area and the equivalent pressure p lb. per square inch below the shoe as indicated by the values stated on the right-hand side of the diagram.

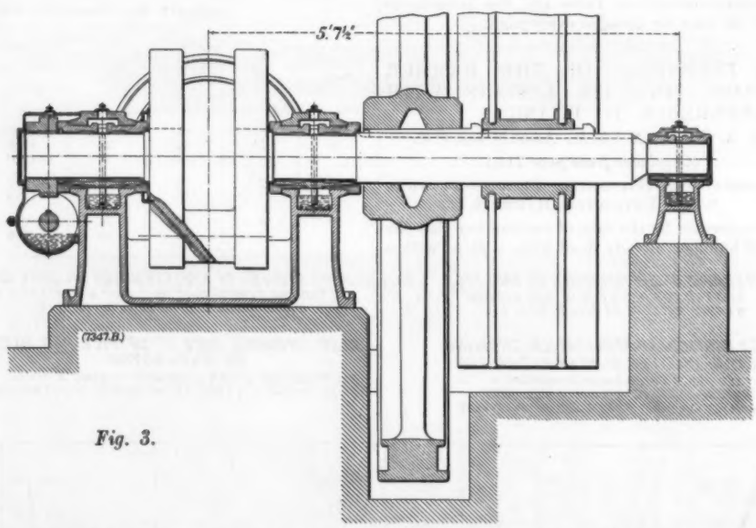


Fig. 3.

In concluding this review of the effects of the hammer blow the author's thanks are extended to Mr. H. P. Lancaster, director of the Simplex Piling Company, for the practical help afforded in enabling him to pursue this subject to a conclusion, and also to Mr. H. T. Garvie, manager of the British Steel Piling Company, for information supplied concerning leading types of steam hammers in general use.

THE BROTHERHOOD COLD-STARTING CRUDE OIL ENGINE.

THE advantages of the cold-starting type of oil engine, capable of starting straight away on fuel of crude quality, are so obvious that it is not surprising that efforts should be made to improve these machines in every direction. An interesting example of this class is illustrated in Figs. 1 to 12, on the present page and pages 747 and 748, which refer to a series of engines developed by Messrs. Peter Brotherhood, Limited, and built at their works at Peterborough.

It is often arranged for cold starting engines to use a higher grade fuel for starting up, after which the machine is turned over to the regular fuel. This is not necessary in the Brotherhood engine, which, on starting with compressed air is supplied at once with the fuel oil of the quality used in running. In fact it is stated that any fuel that can be pumped can be used, such as tar oils; while the engines have been run on sewage grease from town sewers. This grease is in the form of a thick paste, which requires warming before it can be pumped. When the grease has been rendered sufficiently fluid in this way, an engine started on fuel oil and switched at once over on to sewage grease has been able to maintain the same output as on fuel oil. Apart from provision for warming the grease no alteration was made to the engine.

The engine is of the horizontal 4-cycle type, generally on the lines of the Brotherhood standard gas and oil engines. The general features will be followed from the photograph reproduced in Fig. 12, and the sections in Figs. 1, 2 and 3. The inlet and exhaust valves are in line vertically and are operated by a single cam. This construction enables all the stresses to be kept in one plane. The rollers are kept in contact with the cam by means of a spring fastened to both rods, so that this part of the gear is virtually noiseless. The inlet valve is simple, and the bonnet, lantern and valve can be readily removed, as will be clear from Figs. 1 and 2, when the exhaust valve requires grinding in.

Great care has been devoted to the design of the exhaust valve and valve gear. The usual difficulties arise in valves of this class from the fact that the

DETAILS OF COLD-STARTING CRUDE OIL ENGINE.

CONSTRUCTED BY MESSRS. PETER BROTHERHOOD, LIMITED, ENGINEERS, PETERBOROUGH.

Fig. 4.

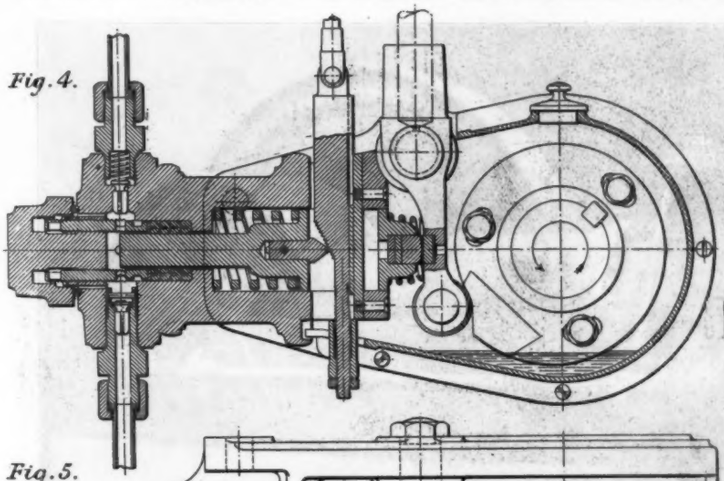


Fig. 5.

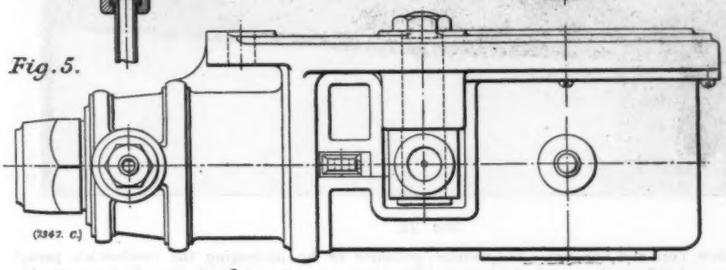
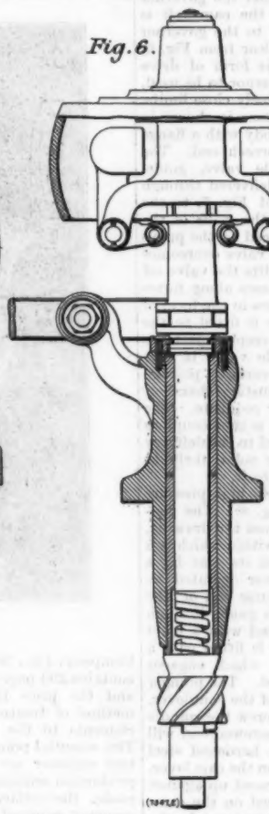


Fig. 6.



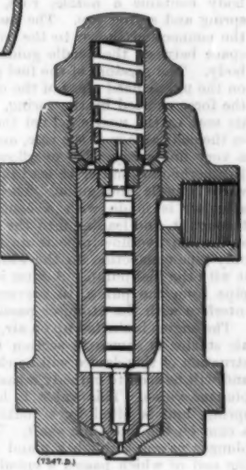


Fig. 7.

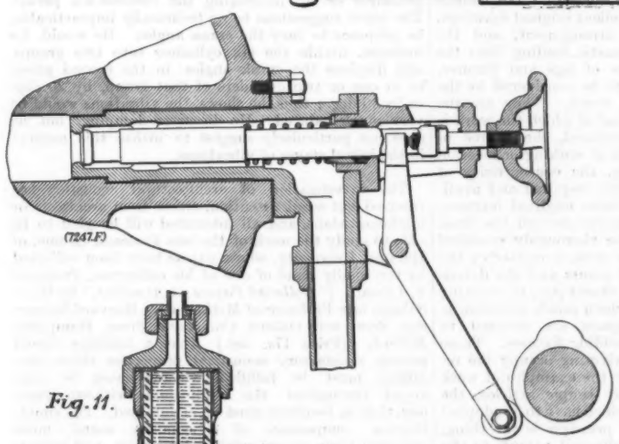


Fig. 8.

Fig. 9.

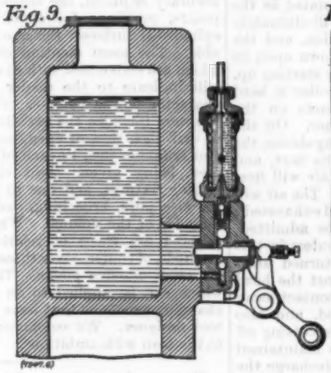


Fig. 10.

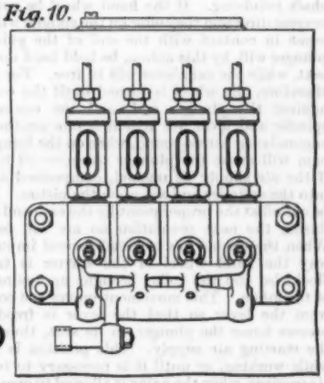
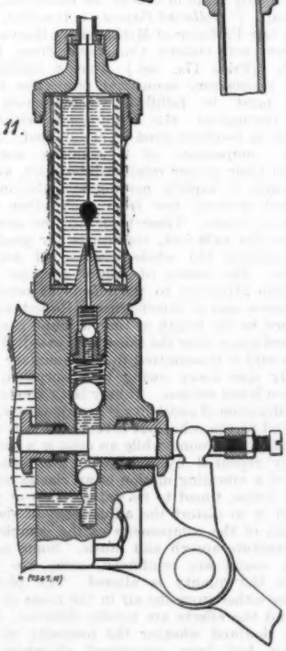


Fig. 11.



operating lever tends to tilt the valve stem slightly in its guide, with the result that when the stem is of small diameter a good deal of wear takes place in the guide. The valve consequently becomes tilted on its seat, causing leakage, while the scoring action of the hot gases soon destroys the valve seat, and passing down the enlarged clearance in the guide removes all the lubricant from the spindle, making bad conditions still worse. With the object of avoiding these troubles, the engine under consideration has been provided with an exceptionally long and larger diameter exhaust valve spindle and guide. In the second place, in order to obviate all tendency to tilt the spindle, the valve is operated by the cam lever through a stirrup arrangement, which gives to all intents and purposes a vertical lift. The stirrup arrangement will be clear from Figs. 1 and 2. From the rocking lever are hung two links to which is attached the stirrup, fitted with a set-screw by means of which adjustments may be made to suit the spindle. It will be noticed the stirrup is hung from an axis above the head of the adjusting screw, and the tendency of the load is to keep the stirrup upright. In the third place, unusual care has been devoted to the lubrication of the valve spindle, for which forced lubrication has been adopted, the oil being pumped into an annular space shown, whence it finds its way to the upper and lower portions of the guide.

All sizes of this type of engine are fitted with an outer bearing (Fig. 3), the crankshaft and camshaft bearings being ring lubricated. The camshaft gear wheels run in an oil bath formed in the gear cover, as will be seen in Fig. 3. Solid injection is employed, the fuel pump being illustrated in Figs. 4 and 5. It is bolted to the camshaft bracket on the breech end, and is driven by a quick-action cam running in an oil bath. The plunger will be seen to have an enlarged head, which works too and fro' in a circular guide. The pump is worked by the cam through a swinging lever fitted with a roller. The lever forces the plunger into the cylinder for the working stroke, the return being effected by a strong spring pressing against a shoulder behind the plunger head. A lighter spring is interposed between the swinging lever and the plunger gear, in order to keep the roller up to the cam face, to ensure quiet running. The engine is governed on fuel, the supply being varied in accordance with the position of the vertical wedge block controlled by the governor. The pump can be primed without interfering with any connection. All that is required is to give the plunger a few forward and backward movements by rocking a short bar fitted temporarily into the socket shown above the swinging lever. The cam is provided with slots and set screws, and can be advanced or retarded to suit the quality of fuel used. In

order to eliminate irregularity of governing due to the skew gear drive from the camshaft, the governor drive is provided with some flexibility. This is introduced by means of a spring, which is fixed to the skew gear pinion and drives by its other end the governor spindle. Any shock or reaction of the camshaft is thus taken up, and is not passed on to the governor proper. The arrangement will be clear from Fig. 6, giving details of the governor. This form of drive enables a very light and sensitive governor to be used, and permits governing between extremely close limits.

The atomiser used with these engines is shown in section in Fig. 7. This has a steel body with a flange for attachment to the face of the breech end. The body contains a nozzle, rose, needle valve, guide, spring and spring cap. The fuel is delivered through the connection shown to the right of Fig. 7, to the space between the needle guide and the walls of the body. The pressure of the fuel produced by the pump on the unbalanced areas of the needle valve overcomes the force exerted by the spring, and lifts the valve off its seat in the nozzle. Fuel then passes along flutes in the conical face of the rose, and issues in the form of a very fine spray. No overflow pipe is fitted to the Brotherhood atomiser to lead off oil creeping past the valve spindle and guide. The needle valve in this atomiser is made with a central overflow passage through it, and leading into the combustion chamber, so that an overflow pipe is no longer requisite. The only pipe connection to the atomiser is that coupling it with the fuel pump. A filter is fitted in the delivery pipe from the pump, to prevent any solid likely to interfere with the atomiser passing into it.

The engine is started up on air, and the high-pressure air starter is shown in section in Fig. 8. The construction of this device will be clear from the drawing, and will be seen to embody a casting within which is a plunger valve. This valve is held on its seat by a spring, and is lifted by a rocking lever operated by a cam on the half-time shaft. The outer end of the plunger passes through a gland into a guide, through the end of which passes a spindle fitted with a hand wheel. The other end of this spindle is fitted with a collar, and with a threaded section which engages with a female thread in the plunger end. The plunger end is slotted to admit the upper end of the cam lever. If the hand wheel be rotated so as to screw the spindle into the plunger up to the collar, the screwed end will protrude inside the slot so far that a hardened steel contact will press up against a contact on the cam lever. The roller of the latter will then be pressed up against the cam, and the valve will be operated on the camshaft revolving. If the hand wheel be rotated in the reverse direction the collar on the spindle will ultimately come in contact with the end of the guide, and the plunger will, by this action, be held hard down upon its seat, while the cam lever will be free. For starting up, therefore, the wheel is turned until the collar is hard against the plunger end, and the contacts on the spindle and lever are touching one another. On the engine being barred round, when on the firing stroke, the cam will cause the plunger to move off its seat, and if the air supply be opened, compressed air will flow into the cylinder and act upon the piston. The air will be cut off at the proper point by the cam and exhausted; during the next revolution no air will be admitted. When the engine has received several impulses in this way the hand wheel of the starter is turned anti-clockwise and the collar brought up against the head of the guide. This movement moves the contact away from the lever so that the lever is freed, and also presses home the plunger on its seat, thus cutting off the starting air supply. This position is maintained while working, or until it is necessary to recharge the air receiver, when the valve is allowed to open. Charging is effected by running the engine with the fuel supply temporarily cut-off. A pointer on the plunger end is made to register with a mark on the spindle collar to ensure the best adjustment for this operation.

Figs. 9, 10 and 11 illustrate the lubricating pump fitted to these Brotherhood engines. The pump is made up with as many plungers as required. The plungers are worked by a cam on the camshaft as shown in the view Fig. 12. Provision is made for adjusting the stroke of the plungers, which are each carried in two stuffing-boxes. The oil is contained in a chamber in the engine bed, a construction that makes it possible to arrange for a large capacity, while also ensuring neatness in outward appearance. The engine air supply is taken from the bedplate casting, and no separate silencer is required for this, so that the supply is perfectly free. The engines described are made in single-cylinder sizes ranging from 20 b.h.p. to 150 b.h.p., and up to 300 b.h.p. with two cylinders.

NOTES ON NEW BOOKS.

Among the increasing number of books that the intelligent machinist can ill afford to dispense with must be included "*Jigs and Fixtures*," by Albert A. Dowd and Frank W. Curtis (The McGraw-Hill Book Company, Inc., New York and London). The volume contains 293 pages and 232 excellent original drawings, and the price is 15*s*. The arrangement, and the method of treatment is systematic, leading from the elements to the special forms of jigs and fixtures. The essential points which must be considered by the tool engineer are clearly laid down. They are the production required, the material of which the work is made, the surfaces to be machined, the degree of accuracy required, the selection of working or location points, provision for chucking, the concentricity of cylindrical surfaces, the machines required and available. The mere mention of these cardinal features, which are elaborated with examplest hrough the book will indicate to the reader the thoroughly practical character of the volume. The subject matter of the chapters includes the essential points and the details of drill jigs, that of open, and closed jigs, of indexing and trunnion jigs, to each of which much attention is now being given. Two chapters are devoted to milling fixtures, and one to profiling fixtures. Those for vice jaws, broaching, and riveting occupy the remainder of the volume. While the examples of work selected are those of relatively simple articles, the methods, of course, cover those which have to be adopted for more massive pieces. The principle is the thing, which can be applied to an unlimited extent, to the changing problems that have to be thought out by the tool designer. We recommend a study of this book to the man with ambitions.

Many engineers are under the impression that the torsional vibrations of engine shafts have received adequate theoretical study, and that at any rate the formulae for their determination, though admittedly approximate, suffice for practical purposes. The adoption of Diesel engines on submarine boats seemed, however, to introduce new problems, both to the German Admiralty and to engineers, during the war, and Dr. Ing. Hans Wydler was charged with their further study in the Vulcan docks at Hamburg. He has published the results of this systematic theoretical and experimental investigation in a small quarto pamphlet of ninety-nine pages on "*Drehschwingungen in Kolbenmaschinenanlagen und das Gesetz ihres Ausgleichs*" [Berlin: Julius Springer, price 10*s*. 10*d*.]. The Vulcan works of Stettin and Hamburg, the Maschinenfabrik Augsburg-Nürnberg, and Professor Frahm assisted him also with the experimental data. Proceeding in his deductions on the lines of Gümbel, which he further develops, Dr. Wydler arrives in this instructive monograph, on which he has obviously bestowed much care and thought, at simplified methods and formulae for the construction of torsion diagrams and the determination of the critical vibrations. As regard their cure, he submits that phase displacements might be obtained by altering the cut-off in some of the engines or, more effectively, by creating counter-pressures or by prolonging the combustion period. The latter suggestions being technically impracticable, he proposes to vary the crank angles. He would, for instance, divide the six cylinders into two groups, and displace the crank angles in the second group or in one or two cylinders of that group, by 20 deg. or by 30 deg.; thus, he shows, the vibrations would be very much reduced. He discusses damping, but he does not particularly suggest to utilise this method in the initial stages of vibrations.

The investigation of architectural acoustics has received but scant attention, either from architects or mathematicians, and all interested will be glad to be able to study the work of the late Professor Sabine, of Harvard University, whose papers have been collected by the kindly hand of one of his colleagues, Professor T. Lyman. ("*Collected Papers on Acoustics*," by W. C. Sabine, late Professor of Mathematics, Harvard University Press and Oxford University Press, Humphrey Milford. (Price 17*s*. net.) That a building should possess satisfactory acoustical properties three conditions must be fulfilled. Sound must be conveyed throughout the auditorium without great loss, that is, loudness must be maintained. The simultaneous components of a complex sound must maintain their proper relative intensities, and successive sounds in rapidly moving articulation must be clear and distinct, free from each other and from extraneous noises. These three are the necessary, as they are the sufficient, conditions for good hearing. They embrace the whole purpose of architectural acoustics. The causes of failure are also threefold, inadequate attention to the effects of reverberation, of resonance and of interference. Reverberation may be defined as the length of time a sound can be heard in a closed space after the cause has ceased. The energy of the sound is transmitted to the boundary walls and gradually dies away owing to absorption, but the extinction is not sudden. It may last some few seconds and the duration of audibility is known as reverberation. It is allied to the echo, but reverberation is a mass of sound filling the room, while an echo is a sharp sound distinctly repeated by reflection. Resonance is the growth of a vibrating motion of an elastic body under periodic forces, timed to its natural rate of vibration. Its effect is to distort the adjustment of the relative intensities of the components of the complex sounds that constitute speech and music. Some notes of a complex sound are reinforced, some are not, and therefore the quality is altered. The phenomenon may arise either from the air in the room or from the walls, and the effects are totally different, though it may be doubted whether the necessity of separate discussion has been recognised elsewhere. Interference, the third element of disturbance is of course due to the existence of trains of waves spreading spherically from the source striking different surfaces

COLD-STARTING CRUDE OIL ENGINE.

CONSTRUCTED BY MESSRS. PETER BROTHERHOOD, LTD., ENGINEERS, PETERBOROUGH.

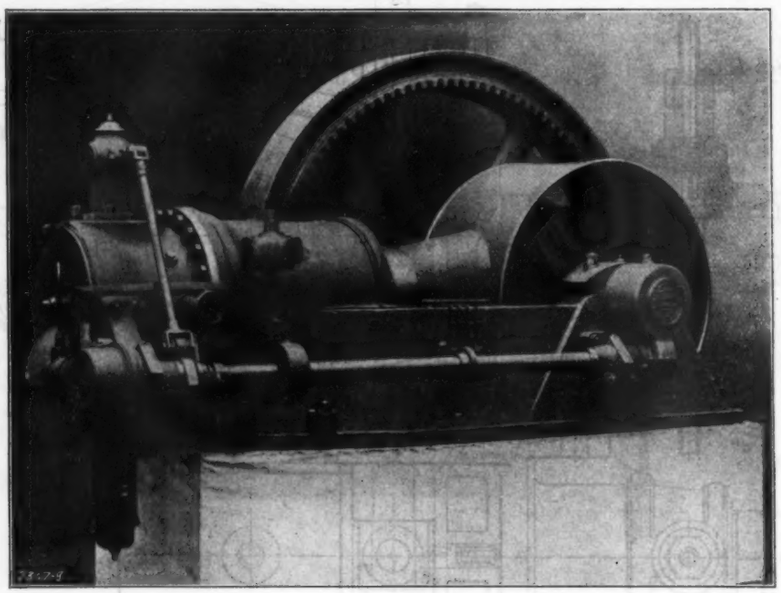


FIG. 12.

ELECTRIC PROPELLING MACHINERY OF THE S.S. "SA

MESSRS. WORKMAN, CLARK AND CO., LIMITED, BELFAST, SHIPBUILDERS; BR

(For Description, see Pag

Fig. 1.

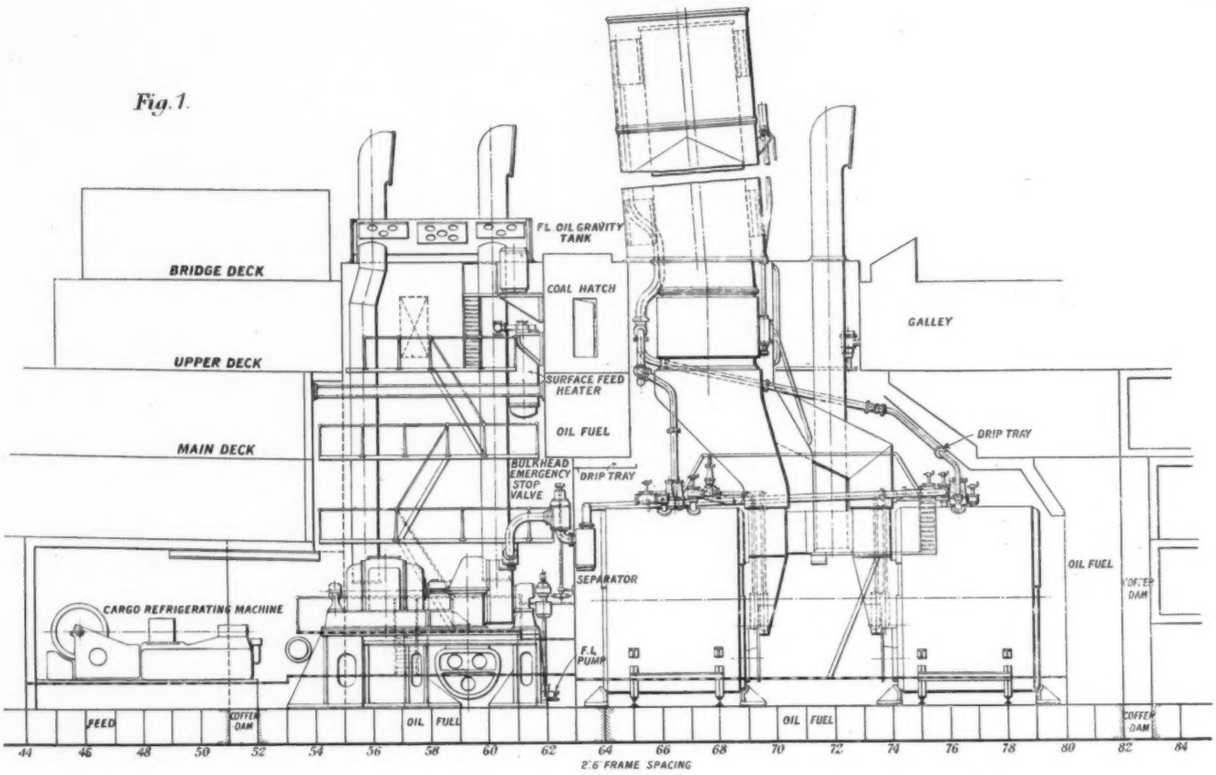


Fig. 2.

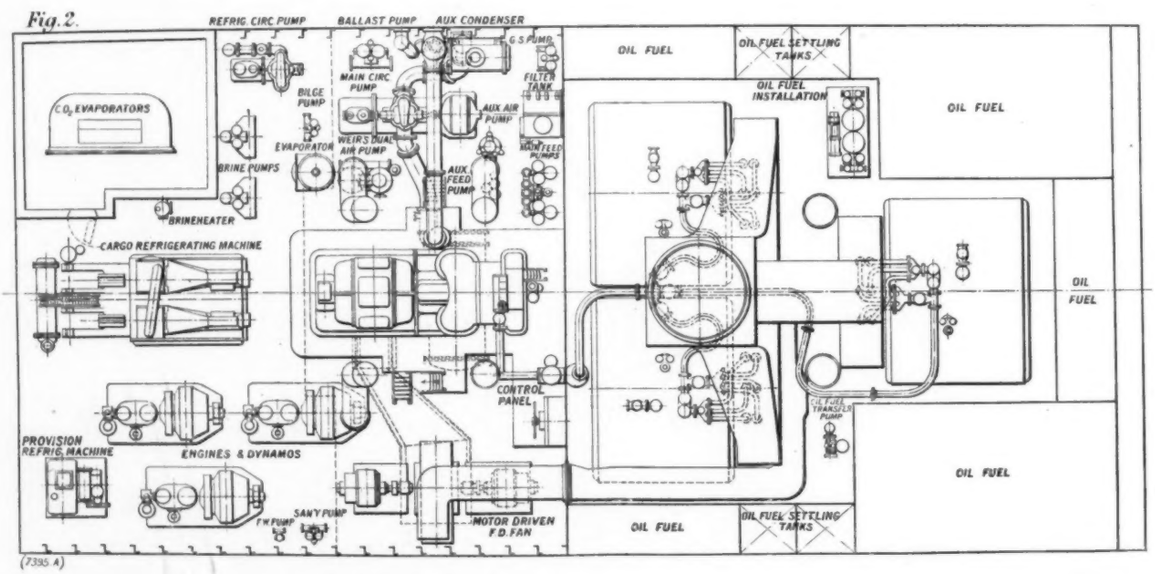


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Fig. 7.

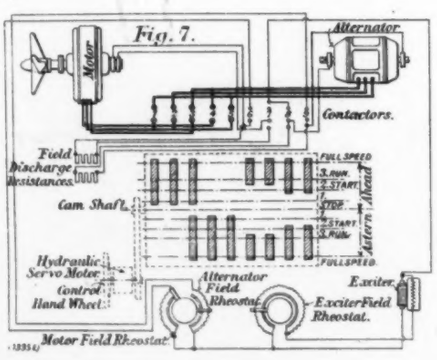


Fig. 8.

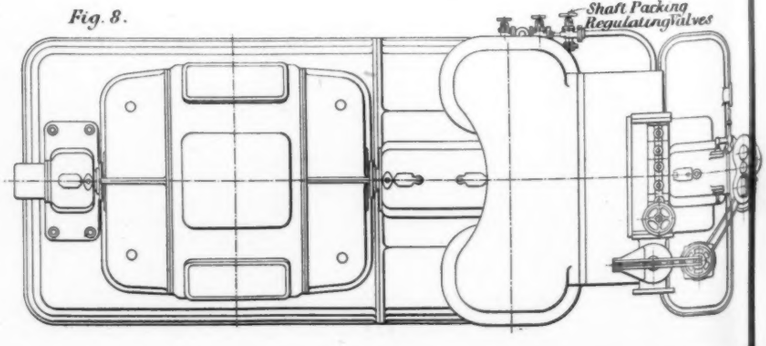


Fig. 3.
VIEW FORWA
IN ENGINE ROO
(Frame 53.)

Fig. 6.
VIEW AT IN
MOTOR ROO
(Frame 25

S. "SAN BENITO" FOR THE UNITED FRUIT COMPANY.

ILDERS, BRITISH THOMSON-HOUSTON COMPANY, LIMITED, RUGBY, ENGINEERS.

ription, *see Page* 749.)

Fig.3.
IEW FORWARD
N ENGINE ROOM.
(Frame 53.)

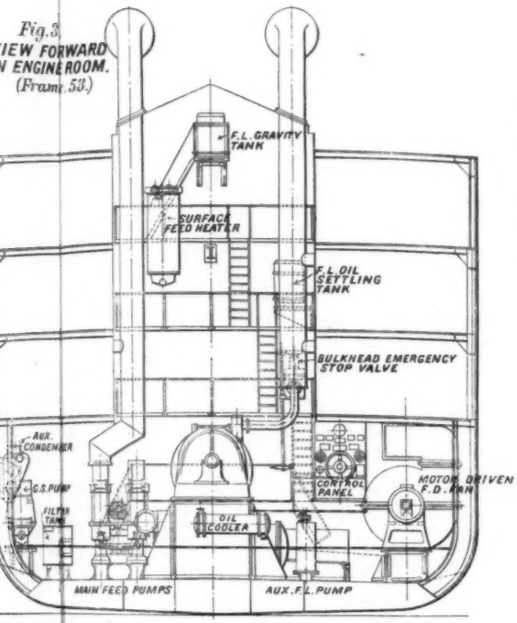


Fig4.

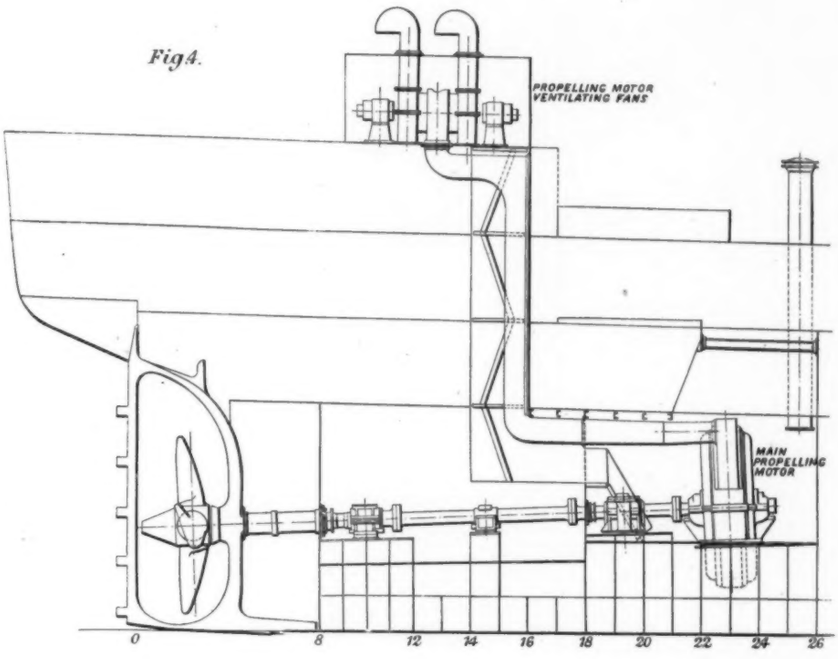


Fig6.
VIEW AT IN
MOTOR ROOM.
(Frame 25.)

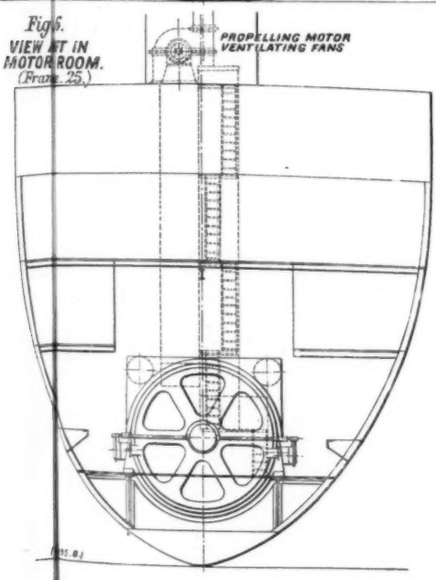


Fig.5.

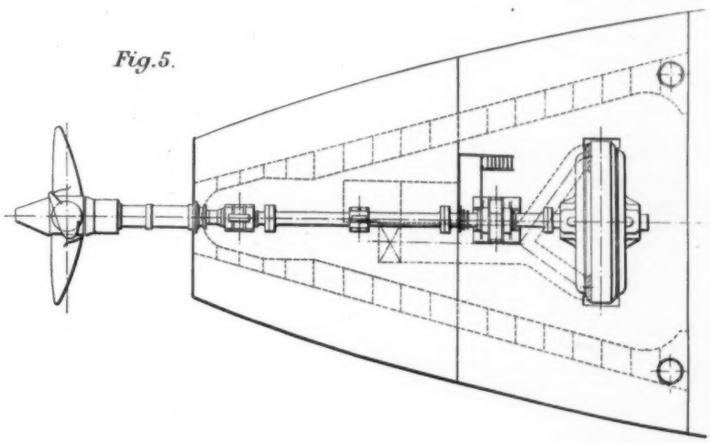


Fig.9.

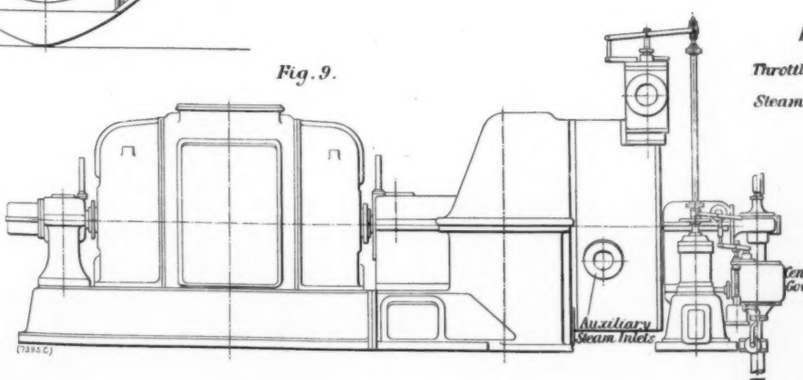
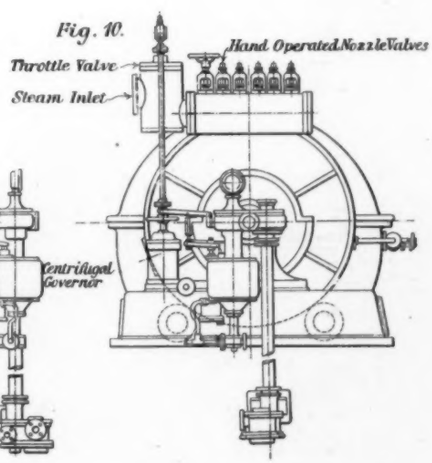


Fig. 10.



of the auditorium and being reflected. According to the length of path before the trains cross or interfere with other sound waves, different results will follow. The condition here considered arises when two trains have travelled so nearly equal paths, that they overlap, and either reinforce or mutually destroy each other. This is the phenomenon of interference, common to all types of wave motion, and its effect is to produce regions in an auditorium of loudness and regions of comparative or even complete silence.

Reverberation is the phenomenon that has been most thoroughly discussed in this investigation, which has extended over many years. These experiments prove that, nearly within the limits of error, the duration of audibility is inversely proportional to the absorbing powers of the boundary walls and curtained material, and is independent of the position of the source of sound or of that of the observer.

Another interesting series of experiments had for its object the "Insulation of Sound" or what may be called the reverse problem of how to prevent sound penetrating walls and obstacles. Layers of felt, frequently relied upon in practice, are shown to be inadequate. If the intensity of sound be represented by 1,000,000, six successive additions of ½-in. felt will reduce the intensity to 11,400; six sheets of iron each separated from the neighbouring sheet by 1 in. of air space, reduced the intensity to 1,520, and a combination of six iron and felt sheets, brought the intensity down to 88, but in no case was total extinction possible.

There is not an abundance of treatises on smith's work. The latest is "*The Blacksmith's Pocket Book*," by Tom Wormald (Scott, Greenwood and Son, 6*s.* net). The subject is treated in eighty-seven pages. The drawings occupy so much space that little room is left for descriptive matter, which is too abbreviated. Neither are the successive stages of forged work shown with sufficient detail. Some drawings are incomplete, others are incorrect. We hope Mr. Wormald, with his practical knowledge, will bear in mind, if a new edition of this book is called for, these friendly criticisms from a reviewer whose knowledge of this class of work has extended over a long period.

In the United States of America, the function of the plumber has apparently a wider range than with us and his duties are taken more seriously. That is the impression gained from a careful examination of the "*Plumbers' Handbook*," compiled by Samuel E. Dibble and published by the McGraw-Hill Book Company, Inc. (price 20*s.* net). The work is addressed to the architect and the engineer, the contractor and the builder, but under the title quoted, these authorities would hardly expect to find much of the information collected. In view of the large ground covered, which embraces metallurgy on the one hand and gas fitting on the other, it has been necessary to enlist the services of a large staff, mainly the colleagues of Mr. Dibble at the Carnegie Institute of Technology, where he is at the head of the heating, ventilating and sanitation department. Professor Leighou writes on metallurgy and chemistry, Professor Ambrose on pumps, Professor Lightcap adds a chapter on mathematics, Professor Blaisdell one on heat, and Mr. Graham, instructor in plumbing, furnishes the glossary of plumbing terms. Outside authorities, as Mr. F. N. Speller, of Pittsburgh, supply the information on pipe standards and pipe dies, Mr. O. W. Kothe that on sheet metal work, and Mr. A. A. Adler is responsible for the article on heating. There is no doubt each of these writers is an authority on the subject of which he treats, and that the information is exact and trustworthy. But owing to the variety of topics discussed, a somewhat superficial treatment is unavoidable, and it might be suggested that some of the writers have attempted to provide more diversified information than the consultant will need, or can be adequately displayed within the space at disposal. For instance, lubrication is a very large subject, and on half a page not much to the purpose can be said, yet Professor Leighou is not afraid to attack it, though lubrication and plumbing seem rather remote. There may, of course, be references in other pages that have been overlooked. Eutectics, again, is a subject that could hardly be discussed profitably within the limits allowed, and the space might have been advantageously allotted to other topics.

Legislative regulation of the industry is more precise than in this country and in some instances might be imitated. It is all to the good, that persons engaged in the plumbing trade should not be allowed to exercise their craft till they have shown their competency before an examining board. In America, such a Board must include the medical officer of health, a plumbing inspector and two practising plumbers. No person can advertise himself as a plumber without the licence granted by this Board, or be allowed to alter, repair, or make any connection with any drain, soil, or vent pipe, or any pipe connected therewith, under a penalty of 10 dols. a day for every day on which he is engaged without due licence.

It is with great satisfaction that we call attention to a new edition of Messrs. Emsley and Swaine's translation of Dr. Gleichen's treatise on "*The Theory of Modern Optical Instruments*," which has just been published by His Majesty's Stationery Office, Kingsway, London (price 12*s.* 6*d.* net), under the auspices of the Privy Council for Scientific and Industrial Research. Seeing that this work owes its appearance in an English dress to the desire of the council to assist the optical instrument-making industry by the circulation of sound technical works, exhibiting the best practice on the Continent, it is a matter for congratulation that the object has been achieved, so far as the absorption of the original edition is concerned. There has been, however, no later edition of the original, and the text of this new English edition does not differ materially from that which preceded it. The translators have, however, added a few fresh notes, dealing with geometrical and physiological optics, but no further additions have been made. In the original, apology was offered for attempting no alteration in the use of symbols, or for not introducing greater uniformity in nomenclature, on the grounds that the delay would be inconvenient and that a revised terminology would have raised difficult and far-reaching problems which could not at the moment receive the attention they deserved. In the interval, however, some advance might have been made in this direction, but we detect none, unless it be a rather long note added by the translators on the method of indicating the direction of measurement in an optical system, certainly a point on which accepted convention should secure uniformity. The Department of Scientific and Industrial Research apparently intended to publish in a separate form, the translators' original work on the subject of range-finders, together with some additional information on other optical instruments, and such distinct announcement is made in the Preface, but a note has since been inserted that the council have abandoned that intention, having "learnt that a publication dealing with modern optical instruments was being undertaken by a firm of publishers, which would deal with such matters." Activity in this direction is to be welcomed, however it may be displayed.

THE ELECTRIC PROPELLING MACHINERY OF THE "SAN BENITO."

At the time of her completion in the autumn of last year, we made a brief reference* to the S.S. San Benito, remarking that she represented an important development in marine work, as far as this country was concerned, in that she was fitted with turbo-electric propelling machinery. We are now able, by the courtesy of the builders, Messrs. Workman, Clark and Co., Limited, Belfast, to give a full account of the machinery installation of this vessel, together with sufficient illustrations to make the descriptive matter clear. The San Benito, we may mention, is the thirty-fourth vessel completed by Messrs. Workman, Clark, for her owners, the United Fruit Company, of Boston, U.S.A., and in common with the other vessels forming this company's fleet, she has been designed for the carriage of fruit from the West Indies to the United States. Her equipment for the stowage and cooling of this perishable cargo embodies the wide experience in this class of work of both the owners and the builders.

Except as regards her propelling machinery, the San Benito is exactly similar to three other vessels in the owners' fleet, which vessels are fitted with triple-expansion engines and have proved very successful and economical in service. The working results obtained with the new vessel should therefore furnish some interesting and valuable data for comparing the two systems of propulsion. To render the comparison as complete as possible, the boilers fitted in the San Benito are similar to those in the three sister ships, and the boiler power, it may be added, is provided on a very liberal scale not only to supply the extensive refrigerating plant, but also to allow a large margin of power to enable schedule times to be adhered to irrespective of adverse weather conditions.

The length of the San Benito, which has a cruiser stern, is 325 ft. between perpendiculars, the moulded breadth being 46 ft. and the depth 31 ft. 9 in. She was surveyed by the British Corporation, the ship and machinery, including the electrical equipment, being classified B.S.* and M.B.S.* The general arrangement of the machinery can be followed by examining Figs. 1 to 6, on Plate XLI, and from Figs. 1 and 2 it will be seen that steam is supplied by three single-ended cylindrical boilers. These are 15 ft. 10½ in. in diameter internally and 12 ft. 2 in. long, and they are each fitted with four furnaces arranged for burning oil fuel on the White system in conjunction with Howden's system of forced draught. The total heating surface is 8,532 sq. ft. and the working pressure is 200 lb. per square inch. Schmidt smoke-tube superheaters, capable of superheating the steam by 200 deg. F., are fitted in the case of the San Benito, this being the only respect in which the boiler installation differs from those of the sister ships.

The electrical propelling machinery has been designed to develop 2,500 s.h.p., with a propeller speed of 100 r.p.m. and is intended to maintain a service speed of 12½ knots. It was supplied by the British Thomson-Houston Company, Limited, Rugby, who by virtue of their association with the General Electric Company of the United States, have the benefit of the extensive experience in electrical equipment for ship propulsion possessed by the American concern. The single turbo-alternator is arranged in the engine-room amidships, as shown in Figs. 1 to 3, on Plate XLI, while the propelling motor, which is directly coupled to the propeller shaft, is situated in a separate compartment right aft together with the main water-cooled thrust block of the Michell type. With this arrangement which will be clear from an inspection of Figs. 4 to 6, the usual shaft tunnel is dispensed with and a cargo space free from all obstruction is obtained. The turbo-alternator illustrated in Figs. 8, 9 and 10, on Plate XLI, is rated at 2,040 kw. at 3,000 r.p.m., and comprises a nine-stage Curtis type turbine of the British Thomson-Houston standard design, suitable for working with steam at 190 lb. per square inch gauge, superheated 200 deg. F., and driving directly a three-phase alternator which is designed to give a normal full-load output of 2,040 kw. at 1,100 volts, 50 cycles. A longitudinal section through the turbine is given in Fig. 11, on page 750, and from this it will be seen that the first wheel is velocity compounded, having two rows of buckets, this being followed by eight wheels, with a single row of buckets each. The supply of steam to the turbine is controlled by five hand-operated nozzle valves, each controlling a group of nozzles, the number of valves opened or closed being such as to give the desired sea speed. This arrangement allows the main throttle to be set full open and full steam pressure to be maintained in the nozzle chest under varying loads.

All exhaust steam from the auxiliaries which is not required for feed heating is admitted to the turbine through one of the two inlets in the casing, passing into the fifth stage when the turbine is working at full power or at any value down to 60 per cent. of full power, and entering the first stage when less than 60 per cent. of full power is being developed. An automatic shut-off valve, fitted in the auxiliary exhaust pipe line, and controlled by the steam pressure in the nozzle chest, cuts off the exhaust steam supply to the turbine whenever the turbine governor comes into operation and closes the main speed control valve during manœuvring periods. During these periods, a spring-loaded valve diverts the auxiliary exhaust steam to the main condenser.

Special governing gear is fitted to maintain any desired turbine speed between the limits of 3,200 r.p.m. and 300 r.p.m., irrespective of the load. For speeds down to 2,500 r.p.m., the control is maintained by a spring-loaded governor, but, for lower speeds and for the manœuvring periods, the turbine revolutions are controlled by an oil-pressure governor, the setting of which is regulated by the movement of the main control hand wheel. An emergency governor, of the out-of-balance ring type, is also fitted, and this closes the emergency stop valve when the turbine speed exceeds 3,000 r.p.m. by 15 per cent.

Two oil pumps, both of the gear type, are driven by a worm on the turbine shaft, one pump supplying oil for operating the manœuvring governor, and the second delivering lubricating oil to a gravity tank, at the top of the engine-room hatch (see Fig. 3), from which all the turbine bearings are supplied. A standby steam turbine driven oil pump is fitted for starting purposes and emergencies, and is controlled by a pressure regulator in such a manner that, if the supply of lubricating oil should fail for any reason, this emergency pump would come into action automatically. Duplicate oil coolers are provided, with the necessary valve connections, to enable either to be cleaned or repaired while the other is in operation, and the lubricating system is equipped with a De Laval motor-driven separator to purify the oil. The main condenser is of the two-flow Uniflux type, and is arranged athwartships, under the turbine, being directly attached to the turbine exhaust branch. This condenser is designed to maintain a vacuum of 27½ in. of mercury with tropical sea temperatures.

The alternator, a longitudinal section of which is reproduced in Fig. 12, on page 750, is of the British Thomson-Houston standard type. It is self-ventilating, the air for this purpose being taken into the rotor at the bottom of the end shields and discharged through the stator core into a duct which leads into the inlet of the forced draught fan. Temperature coils, which are fitted in the windings, enable the temperature of the machine to be read at any moment from a temperature indicator which is fitted on the control board. Fig. 13, on page 751, which is reproduced from a photograph

* See ENGINEERING, vol. cxii, page 481.

ELECTRIC PROPELLING MACHINERY OF S.S. "SAN BENITO."

Fig. 11.

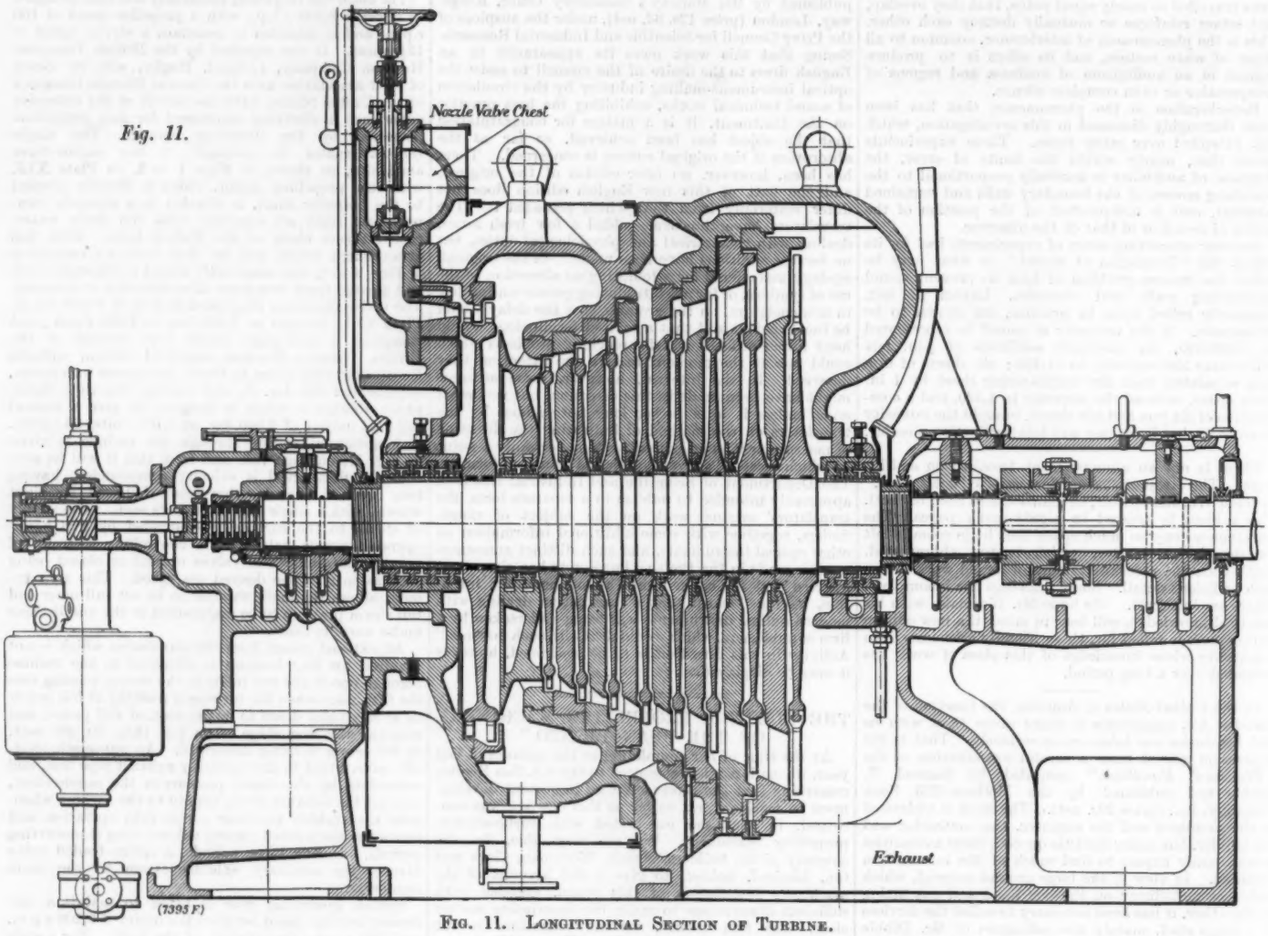


FIG. 11. LONGITUDINAL SECTION OF TURBINE.

Fig. 12.

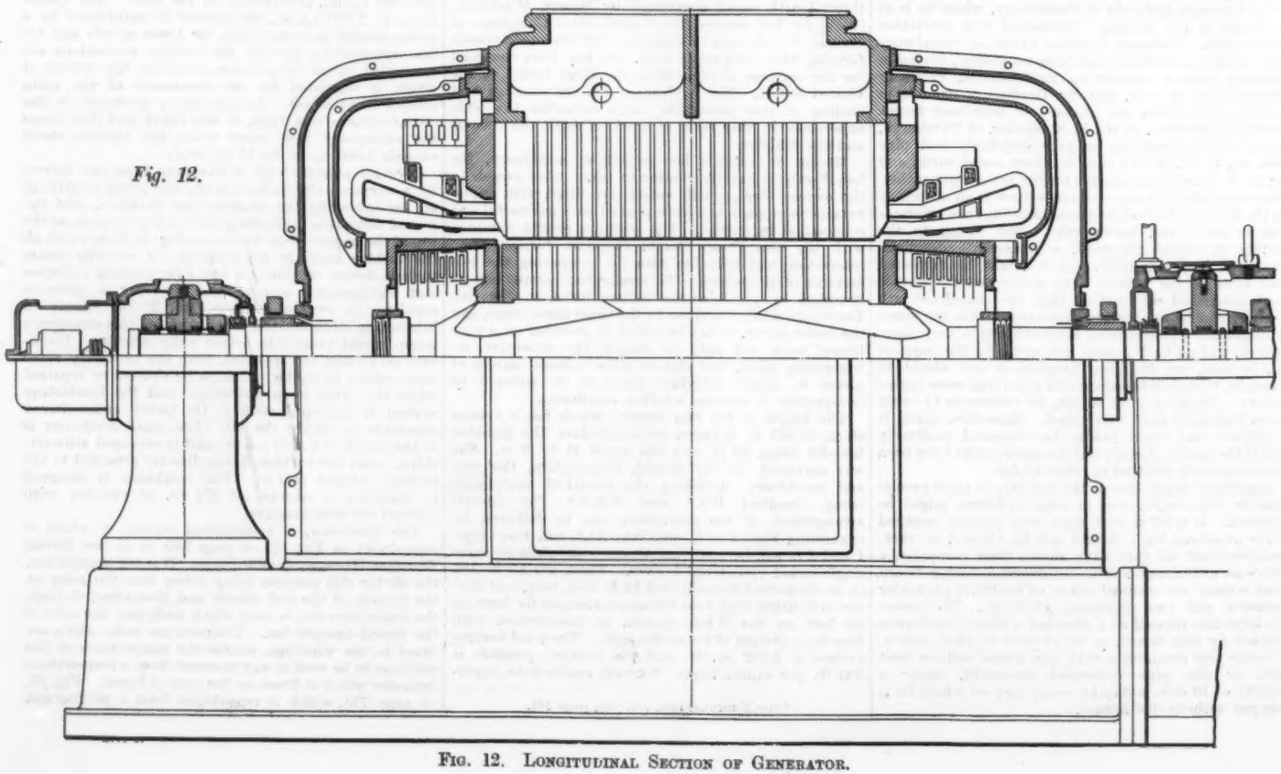


FIG. 12. LONGITUDINAL SECTION OF GENERATOR.

ELECTRIC-PROPELLING MACHINERY; S.S. "SAN BENITO."

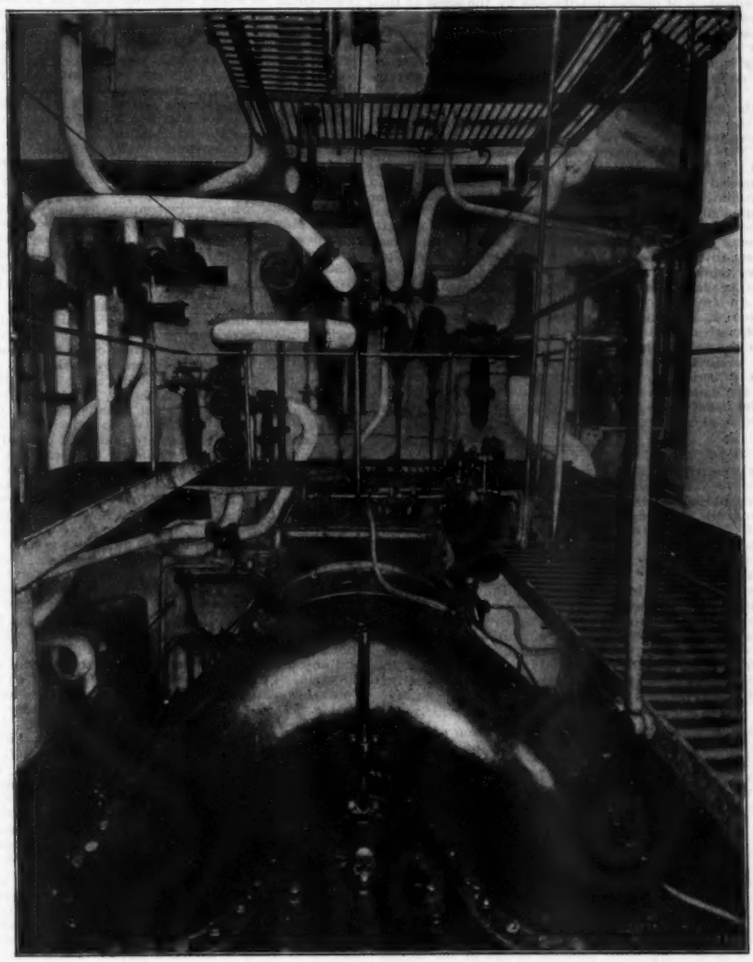


FIG. 13. VIEW IN ENGINE ROOM LOOKING FORWARD.

taken in the engine-room looking forward, shows the turbine end of the turbo-generator set in place; the valve box can be seen in the centre of the illustration. Another view of the set showing the generator end taken from a lower level is given in Fig. 17, on page. 754.

The main propelling motor, which is illustrated in Fig. 15, on page 754, is a 60-pole, three-phase, end-shield type synchronous machine, designed to develop 2,500 s.h.p. at 100 r.p.m., with current at 1,100 volts, 50 cycles. In the design of this motor, special consideration has been given to the propeller characteristics, and the design of both the alternator and the motor has been carried out so as to ensure that the characteristics of these machines are in harmony.

The rotor is fitted with easily-removable pole-pieces which allow the pole-piece and the field coil to be removed together. It should be noted that a synchronous motor possesses great advantages for marine work, in that it is possible to use a comparatively large air gap, which amounts to ¼ in. in the case of the machine we are now dealing with, without impairing the efficiency. A diagram giving the characteristics and efficiency curve of the motor is reproduced in Fig. 14. As in the case of the generator, temperature coils are fitted in the motor windings to enable the temperature to be read on an indicator located on the control board. A separate fan driven by a direct current motor, and clearly shown in Fig. 4, on Plate XLI, is provided for the ventilation of the motor windings. The combination of an alternator and a synchronous motor, of course, constitutes an electrical speed-reduction gear, in this case giving a 30 to 1 reduction between the prime mover and the propeller. Moreover, reversing can be effected electrically while the turbine always runs in the same direction, thus avoiding the necessity for a special turbine for astern running and eliminating all risks attendant on the application of highly superheated steam to this comparatively cold turbine. The arrangement also avoids losses due to the idle turbine wheels running in the reverse direction and, further, with electrical speed-reduction gear, full power is always available for running astern.

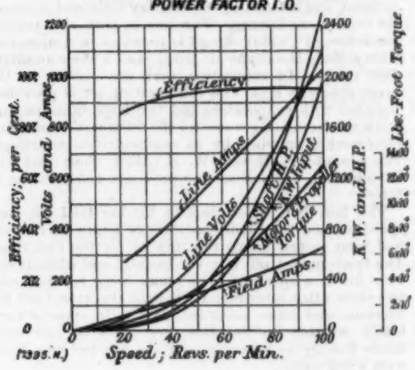
The control gear consists of a contactor unit fitted with five main line and four field contactors, all operated in proper sequence by a camshaft which is situated in the bottom of the unit. A sprocket wheel, which is keyed on the forward end of this camshaft, is rotated by a roller chain which in turn is operated by a servo-motor fitted on the control board. A diagram of the connections is given in Fig. 7 on Plate XLI. The control panel, which is illustrated in Fig. 18, page 754, has fitted on it an indicating wattmeter (calibrated in horse-power), an alternating-current ammeter, an alternating-current voltmeter, a direct-current ammeter for the motor field, a direct-current ammeter for the alternator field, two temperature indicators above referred to for the alternator and the motor windings, and a duplex electrical speed indicator which indicates the speed of both the motor and the turbine. The main control hand wheel, also fitted on the control board, operates the contactors and controls the admission of steam to the turbine. It rotates from the central, or "stop," position through an angle of 165 deg. in a clockwise direction for full-speed ahead, and in an exactly similar manner, but in the opposite direction, for full-speed astern. This hand wheel operates a servo-motor which gives prompt and positive operation of the contactors and makes it impossible for the operator to keep the contactors in a partially open position. In addition, the servo-motor is adjusted to ensure that the manœuvring oil governor is set to the minimum speed before any switching can take place.

The sequence of operations can be followed from the diagram, Fig. 7, when it is assumed, for example, that the ship is going full ahead and it is required to go full astern. The hand-wheel is turned round in the direction indicated, and this action first sets the turbine governor in the minimum speed position, thereby closing down the steam. The fields are then taken off both the motor and the generator, and, when the hand-wheel indicator reaches the "stop" position, the three line contactors for ahead running are thrown out. On passing the "stop" position towards the astern running points, the three line contactors for astern running are closed, and this action is followed by the closing of the generator field contactors on the start point. At this point, the exciter field is automatically strengthened, thus giving increased excitation to the turbo-generator while the motor is operating as an induction machine. As soon as the motor has accelerated sufficiently, as shown on the speed indicator, the hand-wheel is moved to the next point and the motor runs as a synchronous machine. Further movement of the hand-wheel opens up the steam from "dead slow" to "full-speed astern." It must, however, be understood that the whole sequence of operations described takes considerably less time to carry out than is required to follow the description.

Interlocks are so arranged that it is impossible to operate in a wrong sequence, and, as will be seen from the foregoing description, the main line contactors cannot be operated unless the field is off the generator and the circuit is dead. During the whole range of the servo-motor movement from point 3 or "run point ahead," through the neutral point to a similar position astern, the steam control remains in the minimum speed, or "dead slow," position. It should be noted that no large starting resistances are required with this synchronous motor equipment and control system.

60-POLES, 50-CYCLES, 100 R.P.M., 1100 VOLTS, 1960 K.V.A. 2500 H.P.

Fig. 14. CHARACTERISTICS WITH VARYING SPEED. LOAD VARYING AS CUBE OF SPEED. VOLTAGE VARYING AS SQ. OF SPEED. POWER FACTOR 1.0.



A very extensive equipment of auxiliary machinery is provided, and, in this connection, the owners decided to duplicate, as far as possible, the auxiliaries fitted in the other ships of the class, and, by this means to increase the accuracy of the information obtained as to the performance of the main propelling machinery. No attempt was therefore made to extend the application of electrical power for the driving of engine-room and deck auxiliaries beyond what is the owners' general practice, so that the usual steam-driven auxiliaries are largely retained. An exception is, however, found in the case of the 15-in. main centrifugal circulating pump supplied by Messrs. W. H. Allen, Sons and Co., Limited, which is arranged to be driven normally by a 55-h.p. induction motor of British Thomson-Houston make, operating with three-phase current taken from the main alternator at 1,100 volts. Alternatively, the pump may be driven by a compound engine supplied by the pump makers. A Weir dual air pump replaces the engine-driven pump provided in the sister vessels.

There are three auxiliary direct-current generating sets, illustrated in Fig. 16, on page 754, each of 90-kw. capacity, but capable of withstanding a temporary load of 125 kw. The generators were supplied by the Sunderland Forge and Engineering Company, and are driven by compound enclosed forced-lubrication engines by Messrs. W. H. Allen, Sons and Co., Ltd. Two of these sets are normally in operation while the third acts as a standby. One set supplies the excitation current, and the second generates at 110 volts for lighting and for the supply of power to the forced-draught fans, propelling motor ventilating fans, and the fans employed in connection with the cooling of the

cargo spaces. These three 90-kw. sets compare with three 55-kw. sets installed in the sister vessels. Two Weir's feed pumps are provided, operating in conjunction with a Weir multi-flow surface feed heater, and controlled by a float working in a large gravitation filter and hotwell tank.

The forced-draught fan, placed as shown in Fig. 3, is of Messrs. Howden's make, and, following the owners' usual practice, is driven by a direct-current motor made by the Sunderland Forge and Engineering Company. A second similar motor acts as a standby in place of the steam engine provided for this purpose in the sister vessels. The air discharged from the alternator windings is trunked to the fan inlets. The oil-fuel installation was supplied by the builders of the vessel, being constructed under licence from the White Company. Pumps and heaters are fitted in duplicate, and the transfer of oil from the double bottoms to the settling tanks is effected by a large Weir pump designed for this particular duty.

In connection with the oil-fuel installation, arrangements are provided for the re-liquifying of oil which may have become congealed in the double-bottom tanks and suction pipes. The system adopted is known as the "Rand" system, and was installed by Messrs. Row and Davis, of New York. In place of the usual steam-heating grids, with their multitudinous joints and attendant disabilities, the oil, in the first instance, is pumped from the settling tanks into special heaters of patented design and discharged to the tanks and suction pipes it is desired to bring into operation. The oil is discharged into the tank through a nozzle which revolves by reaction, so that the heating effect is distributed over a large area and, in a short time, oil may be drawn from the tank and circulation continued until a suitable temperature is reached. Ballast duties are dealt with by a 9-in. by 10-in. by 10-in. Lamont duplex pump, while separate pumps of similar make are provided for general service, bilge, sanitary and fresh water services. A Weir 30-ton evaporator is fitted, and is fed from the sanitary main and arranged for continuous brining. For duty in port, an auxiliary condenser of Uniflux design is provided in conjunction with a Weir Monotype air pump, and a Weir auxiliary feed pump. In connection with the cooling of the cargo spaces, a large CO_2 refrigerating set is provided, together with evaporators and two large brine pumps, while the circulating water for the refrigerating machine condenser is supplied by an engine-driven centrifugal pump made by Messrs. W. H. Allen, Sons and Co. In addition, a small set for provision refrigerating is fitted.

The San Benito left Belfast for her trial trip and speed runs on the Clyde less than 24 hours after steam had been turned on to the turbine for the first time. The trials passed off very successfully and without the least hitch, a speed of 14·3 knots being reached, and two days after returning to Belfast the vessel left for Valencia and other ports in Spain. In spite of very heavy weather in the Bay, her ports of call were made exactly to schedule, and she left for New York with a full cargo.

The passage across the Atlantic was characterised by almost continuous heavy—and at times exceptionally heavy—weather, the ship passing through the centre of a violent cyclone, but, under the most adverse conditions, no trouble whatever was experienced with the propelling machinery, and the steadiness of the ship and the absence of any "racing" was most noticeable. The San Benito is now engaged on her regular run between Boston and the West Indies, and her performance is being carefully watched in the expectation that her economy will prove to be as marked as her seaworthiness.

THE OPTICAL SOCIETY.

At a meeting of the Optical Society held on Thursday, June 8, Sir Frank Dyson, F.R.S., president, in the chair, the following papers were read and discussed:—

"*Angle Comparators of High Precision for the Goniometry of Prisms*," by J. Guild, A.R.C.Sc., F.Inst.P., F.R.A.S. This paper describes applications of the method of substitution to goniometric measurements of high precision. A simple arrangement is described with which measurements accurate to within one or two seconds can readily be made, and a more elaborate arrangement with which an accuracy of about 0·1 second may be attained. The latter emoodies a method, which appears to be new, of obtaining very minute variations in the direction of a beam of light emerging from a collimator by placing near the focal plane of the latter a "variable prism" of simple design and construction.

"*The Changes in Aberrations when the Object and Stop are Moved*," By T. Smith, M.A., F.Inst.P. If the aberrations of any centred optical system are known both for an object which intersects all rays transmitted by the system and also for the centre of the effective stop, the position in the image space of the emergent portion of a given incident ray is known, and the aberrations in the image of any other object for any stop position can be expressed in terms of those for the first object. The investigation aims to express the relations in the second case in terms of those present in the first when the objects are planes normal to the axis of symmetry whatever the order of the aberration may be.

"*The Classification of Optical Instruments*," by T. Smith, M.A., F. Inst.P. Exception is taken to the classification of optical instruments by the signs of their powers, and an alternative division comprising five classes is proposed, based upon the separation of the four Gaussian constants into two groups according to their signs. This classification cannot be modified by the addition to the system of inverting prisms and the like, and the properties usually associated with the sign of the lens in reality depend upon its class according to the new system. Each class may have systems of positive or of negative power.

"*Note on Achromatism with One Glass*," by T. Smith, M.A., F.Inst.P., and L. M. Gillman, B.Sc. Systems composed of thin lenses of the same kind of glass and achromatised by selecting suitable positions for the components are members of the class A D, B C, so that if the object is real the image is virtual. Apochromatic systems constructed from normal achromatic lenses belong to the same class. The outstanding aberrations for systems constructed of a single glass but belonging to other classes are of considerable magnitude.

"*An Improved Subjective Test for Astigmatism*," by Herbert S. Ryland. The present test has been designed to obviate certain difficulties which patients experience when the usual test card is used. It consists of an opaque disc perforated along two diameters at right angles with a series of square apertures. These apertures and the distances between them subtend angles of 1 ft. at the usual testing distance. The plate is illuminated by diffused light from the rear.

TRANSACTIONS OF THE LIVERPOOL ENGINEERING SOCIETY.—The 42nd volume of the Transactions of the Liverpool Engineering Society, which has just been issued, reprints the presidential address by Mr. J. R. Davidson, C.M.G., and also the papers read during the 1920–21 session. Of these we may mention, "Commercial Fuel Oil Depots," by Mr. G. K. Bell; "Sound in Engineering and Navigation," by Mr. W. D. Kirkpatrick; "Water Power Problems," by Mr. W. J. E. Binnie; "Impact Testing," by Professor W. Mason; "Tunnelling in Water-Bearing Strata," by Mr. R. F. Baker, &c., to indicate the diverse character of this society's work. The volume, which is strongly bound in cloth-covered boards, contains 360 pages and is published by the society, whose address is Royal Institution, Colquitt-street, Liverpool.

DISSOLVED ACETYLENE.—At the invitation of Messrs. Allen-Liversidge, Limited, whose head offices are at 106, Victoria-street, S.W. 1, we were recently able to follow the various processes involved in the production and utilisation of dissolved acetylene by means of a kinematograph film shown by the firm on the occasion of a luncheon held at the Hotel Cecil on Friday last. Acetylene, as is generally known, cannot of itself be compressed into cylinders for storage and transport. The compression can, however, be effected perfectly safely in acetone, which is capable of absorbing 25 times its own volume of acetylene for each atmosphere of pressure. The cylinders used for the purpose are first tightly filled with Kapok down, the acetone is then introduced and absorbed by the Kapok and finally the acetylene is charged in at a maximum pressure of 225 lb. per square inch. As an example of the proportions of the materials used it may be mentioned that a cylinder containing 200 cub. ft. of free acetylene contains 36 lb. of Kapok and an equal weight of acetone. Acetylene supplied in this form is extremely convenient for motor vehicles lighting as well as for a great variety of metallurgical operations in connection with jewellery manufacture, lead burning, soldering and brazing, and the welding and cutting of metals. The two last-mentioned operations were illustrated in an extremely interesting manner by means of ultra-rapid kinematograph pictures taken close up to the work so that the flow of the molten metal could be easily seen.

THE RAILWAY YEAR BOOK.—The 25th annual issue of the "Railway Year Book," a copy of which has just reached us, contains, in addition to the usual features, with which most of our readers are doubtless familiar, a very complete summary of the provisions of the Railways Act, 1921, with maps and particulars of the new groups. Information as to the functions and constitution of the Railway Wages Boards and Councils is also given, and another interesting feature is a table showing the allocation of the first instalment of the 60,000,000*l.* constituting the agreed settlement of the railway companies' claims against the Government. A new article, including a map, describes the London and North-Western Railway as it now exists following the absorption of the Lancashire and Yorkshire Railway, but as grouping is not required by the Act to be completed until 1923, the standard arrangement of the other railway articles is retained; full information as to the progress of grouping and on the railway situation generally is, however, given. Other new features include a review of the progress of electric traction in this country, tables showing the number of employees of various grades on each railway, particulars with regard to power and automatic signalling, and a note on oil-burning on locomotives. The remaining sections of the work have been revised and added to where necessary to bring the whole of the matter up to date. The book, which is rightly described as "the Whitaker of the railway world," is published at the offices of *The Railway Magazine*, by the Railway Publishing Company, Limited, 33, Tothill-street, Westminster, S.W. 1, and its price is 5*s.* net.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Traffic.—All returns for last month show substantial increases compared with the corresponding period last year, due to the miners' strike which was then in progress. The total received during the month was 402,605 tons, an increase of 397,486 tons compared with May, 1921. The total imports for the five months of this year, 1,784,761 tons, represent an advance of 1,021,915 tons on the relative period of 1921. Denaby and Cadeby Mains figure prominently among the chief contributors, supplying 42,555 tons for the month, and 216,318 tons for the five months. A big business was also done by the Brodsworth, Bullcroft, Hickleton, Ramcroft and the Yorkshire Main group, which jointly contributed 83,622 tons for the month, making a total of 360,086 tons for the five months. Exports exceeded 149,000 tons, bringing the tonnage for the year up to the end of May to 763,916 tons, against 179,640 tons for the first five months of last year. Since January last France has been the largest buyer, though last month the biggest quantity, 40,650 tons, went to Germany. Eighty-seven per cent. of the coastwise trade was done with London.

Iron and Steel.—Throughout the engineering section conditions are more hopeful. The Amalgamated Engineering Union settlement promises to give a much-needed fillip to production. The signing on of some thousands of skilled and semi-skilled operatives is held up pending the return of expert craftsmen. The state of order books at the works of machinery makers is irregular. Some concerns have sufficient arrears and new business to carry them over one to two months, while in other cases immediate prospects are poor and depend almost solely upon the developments of the next few weeks. Taking into consideration the minor spurt in foreign and Colonial buying, a slow but steady expansion is looked for. A hopeful feature is that deliveries of pig-iron into the South Yorkshire area, suspended owing to the recent setting down of steel furnaces, are being resumed, and there is a moderate volume of new business passing, mostly at former rates. Makers of tramway rails for delivery to provincial corporations are offering to supply increased quantities at a reduction of 1*l.* per ton, and are making the current rate for special business 11*l.* 10*s.* Though prices of raw and semi-finished materials are subject to substantial revision where the tonnage required is large, quotations generally are firm and any official movement promises to be in an upward direction. Current prices at works are as follow: West Coast hematite, 5*l.* to 5*l.* 5*s.*; East Coast hematite, 4*l.* 17*s.* 6*d.* to 5*l.*; Lincolnshire No. 3 foundry, 4*l.* 5*s.* to 4*l.* 7*s.* 6*d.*; Lincolnshire forge, 4*l.* to 4*l.* 2*s.* 6*d.*; Derbyshire No. 3 foundry, 4*l.* 2*s.* 6*d.*; Derbyshire forge, 3*l.* 17*s.* 6*d.*; bars, 12*l.* to 12*l.* 10*s.*; sheets, 16*l.* to 17*l.* Business with the Colonies in edge and joiners' tools is steadily being resumed, while inquiries from the home automobile and agricultural industries for steel, tools, castings, special parts and fittings are more abundant. File makers' prospects are brighter now that the engineering outlook has improved, though current orders are for small quantities, and price-cutting is rampant.

South Yorkshire Coal Trade.—Collieries are able to meet all demands by working at less than half pressure. At a few of the smaller local pits production has been suspended for a week, but with the gradual expansion which is expected in the steel and engineering industries business is likely to be more active. While there is no further revision of official quotations, prices are subject to frequent alteration, especially in the case of house coal and gas fuel, where orders are keenly sought and bargains can readily be made for large tonnages. Pits have considerable stocks of cobbles and nuts, but slacks are harder owing to a diminishing surplus. A further expansion in export business in blast furnace coke is reflected in a rise of 2*s.* 6*d.* per ton, bringing the current price for shipment to 19*s.* 6*d.* at ovens. Quotations: Best Branch handpicked, 37*s.* to 38*s.*; Barnsley best Silkstone, 33*s.* to 34*s.*; Derbyshire best brights, 27*s.* 6*d.* to 30*s.* Derbyshire best house coal, 25*s.* to 27*s.*; Derbyshire best large nuts, 22*s.* to 24*s.*; Derbyshire small nuts, 15*s.* to 16*s.* 6*d.*; Yorkshire hards, 23*s.* to 24*s.*; Derbyshire hards, 21*s.* to 23*s.*; rough slacks, 8*s.* to 10*s.*; nutty slacks, 7*s.* to 8*s.*; smalls, 2*s.* to 4*s.* 6*d.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Though there is still a very quiet feeling in pig-iron, the tone of the market shows rather marked improvement, and expansion of transactions is rather confidently looked for. Messrs. Cochrane and Co. have rekindled a blast furnace this week on foundry iron, and a basic furnace is shortly to be put into blast at the Redcar Ironworks of Messrs. Dorman, Long and Co. Another cargo of Cleveland iron low in sulphur and phosphorus has been loaded here this week for Atlantic shipment, and there are still good American inquiries for such iron. A small business in Cleveland pig-iron is passing with Scotland on the basis of 96*s.* 8*d.* f.o.t. Grangemouth for No. 3. All other home and foreign transactions in Cleveland iron are on the usual f.o.t. makers' works, or f.o.b. Tees terms, and quotations are:—No. 1 and siliceous—which are still scarce—95*s.*; No. 3 G.M.B., 90*s.*; No. 4 foundry, 87*s.* 6*d.*; No. 4 forge, 85*s.*; and mottled and white, 80*s.*

Manufactured Iron and Steel.—There is little or nothing new in manufactured iron, but fall in prices for certain descriptions of steel have induced a good deal of inquiry. The reductions are the first announced for over eight months and are 20*s.* for boiler plates, and 10*s.* for ship plates, angles, joists and sections. Principal market

quotations for home trade now stand:—Common iron bars, 12*l.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.*; steel angles, 9*l.* 10*s.*; steel joists, 10*l.*; flats, 10*l.*; soft steel billets, 7*l.* 10*s.*; medium steel billets, 8*l.* 5*s.*; hard steel billets, 8*l.* 15*s.*; heavy steel rails, 9*l.* 10*s.*; fish plates, 14*l.* 10*s.*; and galvanised corrugated sheets, 16*l.*

Hematite.—Supply of East Coast hematite is a good deal in excess of requirements, and stocks have recently shown some increase at makers' works, but improvement in demand is anticipated. Nos. 1, 2 and 3 are 96*s.* for home consumption, and the price for shipment to foreign destinations is 95*s.*

Engineers Return to Work.—A rather considerable proportion of the engineers in this district will not get back to work, as employment cannot be found for them, but the re-establishment of peace after the lengthy trouble in this branch of industry greatly improves prospects generally, and should create immediate expansion in demand for iron and steel.

Coke.—Blast-furnace coke is very plentiful, and is weakening in price. Average Durhams are obtainable at 26*s.* 6*d.* delivered.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Now that the horizon is beginning to get a bit clearer with regard to labour and with the members of the engineering union at last deciding to settle their dispute, the outlook generally is much more hopeful, as the early return to work of such a large body of men will have a stimulating effect on trade. The steel works are still very bare of orders and most of the plant is meantime out of commission. Inquiries are fair, particularly on export account, but home consumers have not a great deal of work to give out. The Continental producers have recently been nibbling at this market, and with lower prices than the local makers, have been endeavouring to pick up even the very little business on offer. To obviate that, the Scottish steel makers decided on Friday last, at their meeting in London, to cut prices by 10*s.* per ton, as from Monday of this week. The new quotations are now as follow:—Boiler plates, 13*l.* 10*s.* per ton; ship plates (½ in. and up), 10*l.* per ton; sections, 9*l.* 10*s.* per ton, all subject to the usual extras and conditions. It is hoped that these lower prices will be the means of consumers again entering the market shortly, but the main source of orders is the shipbuilding industry, and until shipowners show a disposition to place some contracts for new tonnage there can be little real activity at the various steel works. Black steel sheet makers are still very quiet, and little business has so far come out of recent inquiries for export lots. Home users are not taking in much stuff, and unemployment is the order of the day.

Malleable Iron Trade.—The position of things in the West of Scotland malleable iron trade is very unsatisfactory as the bookings have been very poor for a long time back. There is a great scarcity of home business, and the foreign trade is hardly worth doing at the prices which have to be accepted to secure it. The current price for "crown" bars for home delivery—in the Glasgow district—is 11*l.* per ton.

Scottish Pig-Iron Trade.—The state of the Scottish pig-iron trade shows little change. The output, which continues on a small scale, is only being partially taken up, and although the price of foundry iron has got firmer lately there has been little or no increase in business. The home demand has been rather slow, but the prospects are a trifle better. Export trade is also quiet, and last week the amount shipped from the Clyde was 396½ tons, of which all but 78 tons went foreign. Quotations are firmly steady.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Conditions in the coal trade have gone from bad to worse. It had been hoped that the intervention of the Whitsun holidays and the three days idleness of the miners would have had a steadying influence on prices. But such has not proved the case. In fact, values have been further reduced, but so far have not brought along business. In numerous cases pits have been rendered temporarily idle by a shortage of trucks caused by wagons being held up at the docks because of lack of trade, while others have been stopped on account of a breakdown at one of the power stations. Buyers generally continue to adopt a hold-off policy, and it is only those with definite business that are able to accurately gauge prices, which generally are on the basis of 26*s.* 6*d.* for best Admiralty large, 26*s.* 3*d.* seconds, 25*s.* to 26*s.* for the leading Monmouthshires, 26*s.* best dry large and 24*s.* to 25*s.* for ordinary dry large, with best steam smalls from 17*s.* 3*d.* to 18*s.*, and ordinaries from 16*s.* to 17*s.* Generally the price of small depends on the figure buyers are prepared to pay for large. Thus a buyer paying 26*s.* 6*d.* for best large could secure best smalls at 17*s.*, but if 26*s.* is paid for the large, then colliery salesmen ask up to 18*s.* for the small. A satisfactory feature of the trade, however, is the fact that exports of coal foreign as cargo in May were the highest for any month in the past three years. In all, 2,305,121 tons of coal were shipped in May, or 500,000 tons more than in April, but it should be pointed out that there were 26 working days in the former month compared with only 23 in April. Of the total 1,511,000 tons were despatched from Cardiff, 367,300 tons from Newport, 269,500 tons from Swansea, 126,600 tons from Port Talbot, and 31,000 tons from Llanelly. Shipments to France amounted to 664,600 tons, to Italy 345,000 tons, to South America 386,700 tons, to Spain 194,200 tons, to Portugal 116,900 tons, to Greece 19,000 tons, to British coaling depots 279,700 tons, and to other countries 298,700 tons.

The Shipping Slump and Ship Repairing.—The effect of the shipping slump on the ship-repairing industry is reflected in the latest report of the Cardiff Channel Dry Docks and Pontoon Company, Limited, which deals with the twelve months ended March 31 last. In the corresponding period a year ago this company made a profit, after allowing for depreciation, excess profits tax, &c., of 49,200*l.* and paid a dividend of 8 per cent., free of tax, to the ordinary shareholders. In the past year, however, the trading results, after payment of income tax from investments, showed a loss of 42,886*l.*, but a dividend of 5 per cent. less tax was paid out of the contingency fund. The company, notwithstanding the loss, is still in a strong position, for the fluid assets exceed the fluid liabilities by a considerable amount.

THE INSTITUTION OF CIVIL ENGINEERS.—The annual conversazione of the Institution of Civil Engineers has been fixed to take place on Tuesday, June 27, at the Institution, at 8.30 p.m.

THE IRON AND STEEL TRADE.—The production of pig-iron in May amounted to 407,900 tons, a slight rise over the production in April and the highest output recorded since the end of the coal stoppage; production is still, however, only 61 per cent. of the monthly average output in 1920. The production included 137,700 tons of hematite, 146,700 tons of basic, 78,800 tons of foundry and 20,300 tons of forge pig-iron. The furnaces in blast at the end of May numbered 110, compared with 112 at the end of April. The production of steel ingots and castings amounted to 462,300 tons, which is also only 61 per cent. of the average monthly output in 1920.

FIRE AT THE LARGEST ENGINEERING WORKS IN HOLLAND.—On the evening of May 31 last, a serious fire broke out in the works of "Werkspoor," which are the largest engineering works in the Netherlands. The greater part, consisting of the pattern shop, turbine workshop, locomotive shops, pattern stores, and welding shop has been destroyed. Part of the foundry has also been destroyed. The greatest loss has probably been caused through the destruction of the turbines for the Dutch cruiser Sumatra and of the engines destined for the steamer Bontekoe of the Kominklijke Pakervaartmaatschappij. A large number of Diesel engines have also been destroyed.

ROYAL SOCIETY OF ARTS: ALBERT MEDAL.—The Albert medal of the Society for 1922 has been awarded by the council, with the approval of the president, H.R.H. the Duke of Connaught and Strathearn, K.G., to Sir Dugald Clerk, K.B.E., F.R.S., D.Sc., LL.D., in recognition of his important contributions, both theoretical and practical, to the development of the internal combustion engine, which in its later forms has rendered aerial navigation possible, and is also so extensively employed in the motor car, and in the submarine, and for many other purposes. The Albert medal was founded in 1863 as a memorial of the Prince Consort, who was President of the Society from 1843–61, and is awarded annually "for distinguished merit in promoting arts, manufactures and commerce."

SAFEGUARDING OF INDUSTRIES ACT.—The Board of Trade have appointed a committee under Part II of the Safeguarding of Industries Act, 1921, to investigate a complaint by the British Electrical and Allied Manufacturers' Association that vulcanised fibre manufactured in the United States of America is being sold, or offered for sale, in the United Kingdom at prices below the cost of production as defined by the Act, and that employment is being, or is likely to be, seriously affected. The chairman of the committee is Sir Bernard Mallet, K.C.B., and the first sitting for the taking of evidence will be held at 11 a.m. on Tuesday, June 20, at 5, Old Palace Yard, Westminster, S.W. 1. The secretary of the committee is Mr. W. W. Hobson, Board of Trade, Great George-street, London, S.W. 1, to whom all communications should be addressed.

SELF-REGULATING X-RAY APPARATUS.—In an interesting collection of modern X-ray and other electro-medical apparatus, exhibited last week at the show-rooms of Messrs. X-rays, Limited, 11, Torrington-place, W.C. 1, in connection with the Congress of Radiology and Physiotherapy, we particularly noticed a self-regulating set for use when it is necessary to subject a patient to the action of the rays for several hours in succession. In such work the tube becomes "harder" so that the current passing through it tends to diminish, but this is corrected by automatically admitting a minute trace of gas into the tube so as slightly to reduce the vacuum. To effect this, a milliammeter in series with the tube is arranged, so that when the current falls below the desired value, the needle of the instrument closes a local circuit which opens a valve controlling the supply of ordinary lighting gas to a small jet. The gas jet, which is automatically ignited by a spark, impinges on a palladium wire fused through the glass walls of the tube, and from the flame sufficient free hydrogen passes through the substance of the palladium into the tube to restore the vacuum, and consequently the high-tension current, to its normal value. When this is the case, the gas valve is closed and the jet extinguished by the means above described, and it is therefore possible to employ the apparatus for many hours with little or no attention. At the same time the physician can be sure that the intended "dose" has been administered.

NOTICES OF MEETINGS.

THE INSTITUTION OF GAS ENGINEERS.—June 20 to 22, at 10 a.m., at the Institution of Electrical Engineers, Victoria Embankment. Annual General Meeting, Tuesday, June 20, at 10 a.m.: President's Address. The following reports will be submitted: Gas Investigation Committee Statement with reference to the Research on Aeration in Atmospheric Burners; Seventh Report of the Gas Investigation Committee, "Carburetted Water Gas Plant with Waste-Heat Boiler," and discussion; Report of Institution Gas Research Fellowship, "The Liberation of Nitrogen and Sulphur from Coal and Coke as Ammonia," by Dr. A. C. Monkhouse and Professor J. W. Cobb, C.B.E., B.Sc., F.I.C.; Report of the Life of Gas Meters Committee, and discussion. Wednesday, June 21, at 10 a.m., papers to be read and discussed: "Some Gas Burners and a Moral," by Dr. Charles Carpenter, C.B.E., M.Inst.C.E.; "Increasing the Rate of Carbonisation of Coal," by Dr. Geoffrey Weyman; "Reconstruction Work at Beckton," by Mr. W. B. Leech. Thursday, June 22, at 10 a.m.: Welcome to the Société Technique de l'Industrie du Gaz en France. Friday, June 23, at 9.30 a.m., Visit to the Beckton Works of the Gas Light and Coke Company.

THE INSTITUTION OF MINING ENGINEERS.—June 20 to 22, at the Cutlers' Hall, Sheffield. General Meeting, Tuesday, June 20, at 11 a.m. The following papers will be discussed: "The Air-Cooling Plant at the Morro Velho Mine, Brazil," by Mr. Eric Davies, B.Sc.; "Stainless Steels," by Dr. W. H. Hatfield. Visits to Works. Wednesday, June 21, at 10 a.m.: "Methods of Working the Barnsley Seam of the South Yorkshire Coalfield," by Mr. H. Rhodes and Mr. M. Rhodes; "Rock Temperatures in the Coal-Measures," by Mr. J. Ivon Graham, M.A., M.Sc.; "The Rate of Absorption of Poisonous Amounts of Carbon Monoxide by the Blood," by Mr. A. P. Veale. Visits to Works. Thursday, June 22, at 9 a.m., Visits to various Collieries.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—Wednesday, June 21, to Saturday, June 24, at the City Hall, Cardiff. Annual General Meeting, June 21, at 10 a.m.: Presidential Address. Papers to be read and discussed: "Town Planning and Re-planning in Great Britain," by Mr. H. H. Humphries, M.Inst.C.E.; "Town Planning and Re-planning Abroad," by Mr. Thomas Adams. Thursday, June 22, Trials and Demonstrations of Plant. Town Planning Exhibition. Visits. Annual Dinner in the City Hall at 7.30 p.m. Friday, June 23, at 9.30 a.m.: "The Mechanical Equipment of a Municipal Works Depot and Scavenging and Cleansing Department," by Mr. F. Wilkinson, M.Inst.C.E.; "The Mechanical Equipment of a Highways Department," by Mr. A. Dryland, M.Inst.C.E.; "Mechanical Transport," by Mr. Thomas Molyneux; "Electrical Vehicles for Municipal Work," by Mr. R. B. Mitchell, M.I.E.E.; "Heavy Oil Fuel Lorries for Refuse Collection," by Mr. G. Bertram Hartfree, F.S.I.; "The Mechanical Equipment of Waterworks," by Mr. G. R. Collinson, B.Sc., A.M.Inst.C.E.; "Cardiff Housing Schemes: Organisation and Realisation," by Mr. B. Price Davies, M.S.A. Saturday, June 24: "City of Cardiff Waterworks, Taff Fawr Section, Breconshire," description by Mr. C. H. Priestley, M.Inst.C.E. Visit to new impounding reservoir in course of construction.

THE INSTITUTION OF RAILWAY SIGNAL ENGINEERS.—Wednesday, June 21, at 3 p.m., at the Institution of Electrical Engineers, Victoria Embankment, W.C. 2. Papers entitled "Light Signals," by Mr. H. E. Fawkes, Member, and Mr. W. J. Sadler, Associate Member.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, June 21, at 5 p.m., at 49, Cromwell-road, South Kensington. The following papers will be read: (1) "Report on the Phenological Observations for 1921," by Mr. J. E. Clark, Mr. H. B. Adames and Mr. I. D. Margary; (2) "An Observational Test of the Geostrophic Approximation in the Stratosphere," by Mr. L. F. Richardson, B.A., F.Inst.P., Dr. A. Wagner and Dr. R. Dietzius.

ROYAL SOCIETY OF ARTS.—Friday, June 23, 1922 at 4.30 p.m. "Irrigation Enterprise in India." By F. W. Woods, Esq., C.I.E., late Chief Engineer, Irrigation Department, Punjab. The Right Hon. Lord Lamington, G.C.M.G., G.C.I.E., Governor of Bombay, 1903–7, will preside.

YEAR BOOK OF WIRELESS TELEGRAPHY AND TELEPHONY.—The edition of this reference book, which has just been published for the current year, contains a number of valuable new features calculated still further to increase its utility to the large and increasing circle of persons interested in wireless telegraphy. The bulk of the work is, as usual, occupied with the laws and regulations relating to the use of wireless telegraphy in all countries of the world, with lists of land and ship stations, and with articles describing the technical progress of the art in various countries. A number of special articles are, however, included, and of these we may mention one on the earthing resistance of antennæ by Dr. Meissner, and another on recording wireless signals by Dr. Abraham. All the standard sections have been thoroughly revised, and this revision has been particularly thorough in the case of the meteorological section, the importance of which has been greatly augmented by the development of commercial aviation. An entirely new feature of the current year book, which will be appreciated by all classes of users, is the inclusion of a large map drawn so that the true distance and direction from London of any wireless station in the world can be obtained by reading a scale placed on the map. The price of the year book is 21*s.*, and it is published by the Wireless Press, Limited, 12 and 13, Henrietta-street, Strand, London, W.C. 2.

ELECTRIC PROPELLING MACHINERY OF S.S. "SAN BENITO."

(*For Description, see Page* 749.)

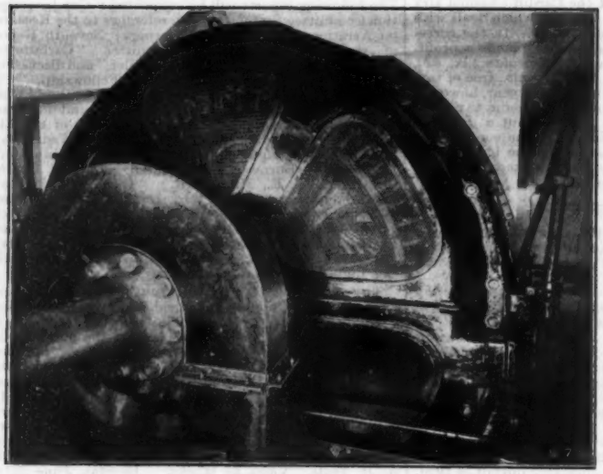


FIG. 15. MAIN PROPELLING MOTOR.

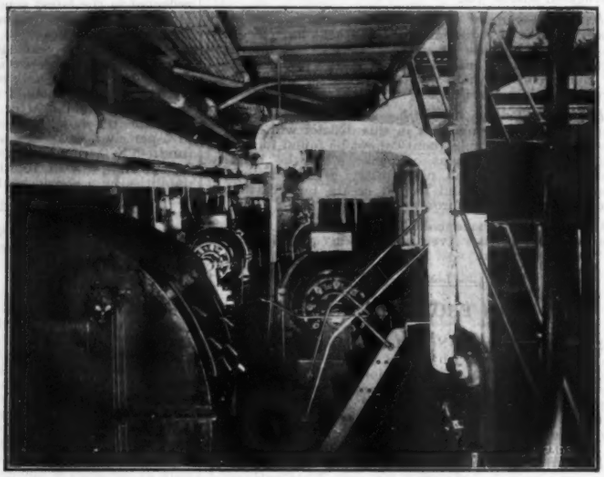


FIG. 16. AUXILIARY ELECTRIC GENERATING SETS.

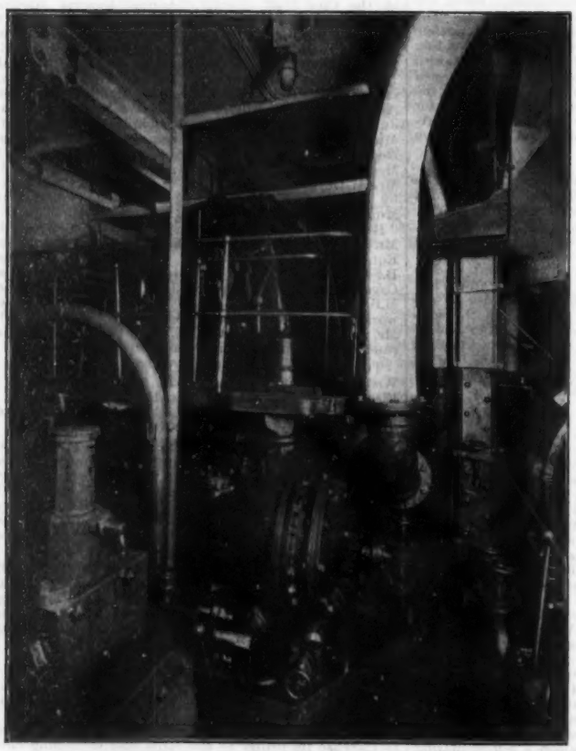


FIG. 17. TURBO-GENERATOR SET FROM GENERATOR END.

FIG. 18. CONTROL PANEL.

THE ELECTROLYTIC MANUFACTURE OF COPPER WIRE.—On June 7, a demonstration of the principle of making wire by Mr. Sherard Cowper-Coles process was given by Messrs. Metals Reproduction, Limited, of 40, Grosvenor-place, S.W. 1, to a number of gentlemen interested in wire manufacture. The process consists in electrically depositing copper in the form of a disc or of a cylinder upon a surface previously engraved with a fine spiral line. The effect of this line is to cause a plane of easy cleavage in the deposit, so that the copper can be readily torn off in the form of a rectangular strip. One passage through rolls, and about two passes through dies is then sufficient to produce wire of any required gauge from a strip of appropriate dimensions. Figures were given tending to show that wire could be manufactured in this way at much less cost than by the usual methods. The strip could, moreover, be deposited from scrap copper, with a further saving of expense.

FOUNDRY PLANT AND EQUIPMENT.—The fuller realisation of the importance of reducing foundry costs and at the same time of improving the quality of castings brought about within the last few years, will certainly result in more consideration being given to the productions of manufacturers who specialise in foundry plant and equipment. A firm having unique experience in this class of work is Messrs. J. W. Jackman and Co., Limited, of Vulcan Works, Blackfriars-road, Manchester, and Caxton House, Westminster, London, S.W. 1, and the exceptionally comprehensive catalogue of their products just issued is well worthy of careful attention by all interested in foundry management. It is, of course, impossible for us to deal here with all the items of plant and equipment enumerated in the catalogue, but an idea of the nature of its contents may be gathered from the fact that the various sections into which it is divided are devoted to requisites and sundries, melting equipment, metal-recovery machinery, sand-preparing plant, moulding machines and appliances, core-shop equipment, cleaning and dressing plant for castings, air compressors, lifting and transporting plant, testing machines, and laboratory equipment. Reasonably complete information relating to all productions included under these headings is given in the catalogue, which is very fully illustrated, but we notice that the firm maintains at its Manchester works a demonstration plant in which prospective clients, by appointment, can see the appliances they are interested in under actual working conditions. It will be obvious that when circumstances permit a visit of this kind to be paid, much more useful information can be obtained than it is possible to convey in a catalogue. The catalogue to which we are referring, however, is well arranged, and a general index to the contents is given. Practically every item is coded to facilitate telegraphic inquiries.

ENGINEERING.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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ENGINEERING.

FRIDAY, JUNE 16, 1922.

GOVERNMENT ASSISTANCE TO INDUSTRY.

ALTHOUGH the undesirable features of the present system of unemployment doles will be fairly generally admitted, yet the development of the modern social conscience would prevent most people from suggesting that it should be withdrawn, unless some aid of a more satisfactory kind could be substituted. A trade depression such as that we are now experiencing may, of course, partly be met by relief works. This is an old remedy, but is probably being applied to a greater extent now than ever before. In the fact that the beneficiaries are required to do some work for the payment they receive, the system has advantages over doles, but in practice it has been found to carry evils of its own. As the job in hand is undertaken mainly to give a portion of the unemployed something to do, it is apt to take on the air of a charity matinée at which one need not be too critical about the way the performers comport themselves. This condition, added to the fact that hands are taken on because they are out of work and not because they necessarily have any fitness for the work required of them, has in many cases resulted in the performance of indifferent work at such high cost that it is probable the locality concerned would have been better off in the long run if the men had simply been maintained by the Poor Law Guardians.

The Labour Party in the House of Commons has more than once suggested that the great spending departments of the Government should assist at times of trade depression by so spreading out their large contracts over the years that the larger jobs should be put in hand in lean years when general trade was bad. This idea has received a considerable amount of attention recently and some effort has been made to fall in with it. No general policy of this kind extending say over a decade has, however, ever been adopted and it is doubtful if it ever could. When important work is put in hand by, say, the Post Office or Admiralty, the presumption, and one trusts the fact, is that the development of the country's trade or interests has reached a stage when the work is necessary, and the country's trade and interests generally must suffer if the matter is deliberately postponed for some years until a lean period supervenes. If work is put in hand before it is required this objection will not apply, but if this is done it must be remembered that the department concerned will have to carry the cost of an expensive work which for the moment it does not require. The matter becomes not greatly distinguishable from an ordinary relief work, except that presumably it would be carried out by ordinary commercial methods. This last feature is important and inclines one to support the proposal.

It is probably fair to say that the majority of relief works which are put in hand cover useful construction which, although not usually revenue earning, yet are to the public convenience or advantage. Such examples as road widening, the construction of parks and land reclamation fall generally in this class, although the latter may possibly be revenue-earning in certain cases. It is not generally speaking the type of work which has been done, but the way in which it has been done, which has given relief works a bad reputation, and if they could be looked upon simply as ordinary activities, pushed forward to meet unemployment, but still treated as ordinary activities it would be decidedly to the general advantage. If relief works were carried out by contract just like any other public activity they might not employ quite so many men, but they would employ them much more efficiently.

It may be objected to this that relief works are essentially put in hand to create employment, and that anything which would tend to limit the number of men they employ would act contrary to the idea on which they are undertaken. This in its limited way is true, but if relief works are undertaken also because they are superior as a method to unemployment doles, then there is something to be said for taking full advantage of such superiority. The most important thing at a time like the present is to do everything possible to foster genuine activity. If it is decided to carry out a road widening with this as one of the objectives, more genuine activity is created by putting the work in the hands of contractors who will see that the men they take on do a day's work for a day's pay, than carrying it out on semi-charity lines, and employing as navvies men who are physically incapable of doing a day's work with a shovel. It may be said that a road widening chiefly calls for navvies and labourers, and that such a procedure as that suggested does nothing for out-of-work clerks. This is not correct. All genuine activity creates other activity, and the navvies and labourers who are drawn to the contract must come from somewhere. A proportion are probably drawn from other employment for which they are less fitted. This is to the general good. Vacancies are provided for more suitable men, and the community comes a little nearer to the ideal utilisation of its manhood.

Probably the best arrangement for rendering general assistance during a period of bad trade which has ever been devised, is furnished by the Trade Facilities Act by which State credit is made available for loans required by private enterprise. A scheme of this kind must naturally be used with discretion, but little objection can be raised to any of the activities which have been assisted up to the present.

Of such schemes, one of the most striking is the guaranteed loan which is being raised for extensions and alterations in connection with the Underground Railway of London. This important work, which was inaugurated on Monday last, when a start was made with the extension of the Hampstead Railway to Edgware, is referred to elsewhere in this issue. Speaking at the ceremony Lord Ashfield pointed out that the arrangement formed a particularly happy example of co-operation between the State and private enterprise. A valuable work was being put in hand, and employment would be given to very many men without a penny of the cost falling on the taxpayer; yet without the assistance of his credit the necessary funds could not have been raised. When Lord Ashfield states that not a penny

of the cost of this work will fall on to the taxpayer he is almost certainly absolutely correct, but it cannot be argued from this that the State can back the finance of private industry to an indefinite extent. It is because the Trade Facilities Act is of comparatively limited application that it is financially innocuous. Were the State to finance private enterprise right and left, its credit would quickly suffer, and the taxpayer would find that he was very much concerned in the matter. Kept within its own limits the Act is an admirable one, and will materially assist in the present period of unemployment. In view of its origin and intentions, the Act naturally specifies that all work carried out with its assistance shall promote employment in the United Kingdom. All materials have to be purchased at home, and special permission is required if this rule is to be departed from.

The point of view that funds spent on home-made material benefit the country and particularly the labouring classes, has obtained many adherents as a result of the unfortunate period through which we have been passing, and it was interesting to note how the point was dwelt on during the discussion in the East India Loans (Railway and Irrigation) Bill in the House of Commons some few weeks ago. The purpose of the Bill is to enable the Secretary of State in Council of India to raise loans of £50,000,000 in the United Kingdom as, or when, required, for railway and irrigation purposes. The loans are not guaranteed in any way by the Government of this country, and the Bill is purely permissive. The Indian Government has no power to float such a loan in this country without permission by special Bill. The point brought forward by many speakers in the House of Commons was that a clause should be inserted in the Bill requiring money raised in this country to be spent in this country. The Government held that such a condition could not be imposed, but much sympathy must be felt for the idea that the country's money should as far as possible be spent in giving work to its own people, especially in times of stress.

This matter is not one in which only Government loans are concerned. There are very many mining, railway and other companies operating with British capital in foreign countries. A large proportion of the necessary stores and machinery for such companies are purchased in the open market—normally in the cheapest market. This procedure can be defended, but it is well that the shareholders and proprietors of such companies should remember that in as far as such material can be purchased in this country, such purchase by improving British trade, ministers to their own prosperity. Anything which extends the useful activity of any class or trade, in this country favourably affects the whole community and reacts to the benefit of all other classes and trades.

THE END OF THE ENGINEERING DISPUTE.

THE engineering dispute has come—or, to give due regard to the attitude of the boiler-makers, is coming—at last to the end which has been clearly inevitable ever since Sir William Mackenzie issued his report on the causes and circumstances of the dispute. It arose out of a desire on the part of extremists in the trade union ranks to gain ultimately the control of the employers' factories, and it has ended—or is ending—in their defeat and in the vindication of constitutional government. The loss entailed by the dispute on both sides and on the community in general is deplorable; but the employers, and Sir Allan Smith as their leader, are nevertheless to be congratulated on having stood firm for the fundamental principle that, with all proper regard to the interests of the workers, the management of the factories must be in the employers' hands.

Mr. Brownlie has experienced the tragedy to which a certain other well-known trade union leader must now be well accustomed, of having to lead in a cause in which he cannot have believed; but it is to his credit that at the end, when the final ballot for a resumption of work was being taken, he advised his members in clear and unmistakable words to accept the employers' terms and go back to work. For the terms are reasonable. Their general principles are stated at the outset to be that the employers have the right to manage their establishments and the trade unions have the right to exercise their functions; and that although changes in shop conditions may be necessary in the process of evolution it is not the intention of the employers to create any specially favoured class of workpeople. It is also provided that where any class of workpeople is displaced by reason of any act of the management, for example, by a change in working conditions, consideration is to be given to the workpeople so displaced with a view to affording them other work in the establishment, suitable to their qualifications, if that can be done. It would have been better if Mr. Brownlie could have spoken out sooner; but he knew his men and his own difficulties, and no doubt he chose the right time. Swinburne, in one of his best poems, has given it as a matter for brief thanksgiving that even the weariest river winds somewhere safe to sea, but it is to be hoped that the settlement of this long-drawn dispute—and the general thanksgiving which the prospect of settlement has evoked—will be not brief but lasting and that the employers and all the trade unions—those who have previously worked under the procedure for avoiding or dealing with disputes and those who now come under it for the first time—will be able to work together for the future in peace. It is clear, however, that industrial peace is not to be secured merely by any artificial means, such as the national conference which Mr. Hodges recently suggested. It can be secured only if the rank and file are wisely and ably led, and follow wise and able leaders. In the present case there would have been no dispute and no lock-out if the members of the Amalgamated Engineering Union had not made the ruinous error of rejecting the memorandum of November, 1921, which their executive had provisionally accepted.

RECENT PHOTO-ELASTIC RESEARCHES ON ENGINEERING PROBLEMS.

ON Wednesday evening last, the 14th inst., Professor E. G. Coker, F.R.S., delivered in Paris, at the Hall of the Société des Ingenieurs Civils de France, an interesting lecture bearing the above title. This lecture, which formed an item in the programme of the meeting of the Institution of Mechanical Engineers at Paris, was illustrated by experiments and colour photographs, and described the methods of photo-elastic investigation, and the latest forms of apparatus used for the measurement of stress in transparent models of the parts of machines and structures. Some recent researches were described in detail, and the lecturer showed by aid of stressed models some of the salient features of stress concentration in tension test specimens similar to those described in our issue of January 7, 1921.

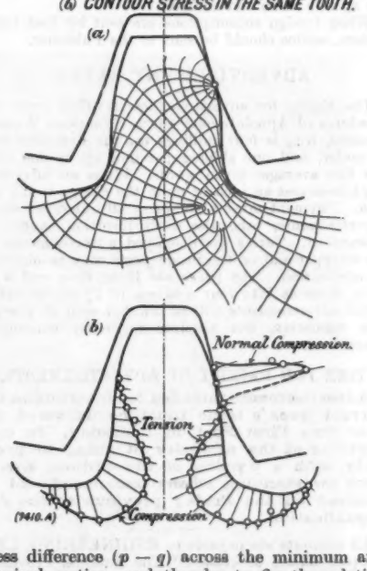
Some simple examples of contact stresses led up to the stresses experienced in the sliding contact pressures in spur wheels and worm gears, in which the oblique pressures between the teeth and worm threads cause high stresses at the surfaces in contact, and also at the roots. In this section some recent measurements of the stresses at the contours of spur wheel teeth were described, and the changes in the directions and magnitudes of the stresses traced for the whole period of contact. A typical example of this kind is shown in Fig. 1, in which the upper part of the diagram shows the lines of principal stress in a tooth, and the lower part shows the contour stresses with maximum values at the roots and at the surfaces in contact. The stress distribution is obviously of a complicated character, and it seems apparent that the usual methods of calculating the stresses in teeth by considering them as cantilevers can only be a very rough approximation of the truth.

The lecturer next proceeded to describe his experimental researches on the action of cutting tools, and by aid of the actual machines and apparatus described in our issue of May 5 last (*vide* pages 561 and 564 *ante*) he demonstrated by projection on the screen the principal features of interest observed in the action of turning, planing and milling cutters operating in a field of circularly-polarised light, so that the stresses which occur were visible to the audience. In a final section the lecturer described a recent comparison of the stress systems produced in models of English and French standard cement briquettes, which he had made with the help of his research assistants, Messrs. E. F. Anderson and T. Fukuhara.

The cement briquette is of particular interest and importance to the civil engineer, since the manufacture and use of cement has an international character like steel, and there is no doubt that for both materials the establishment of standard tests of scientific precision, acceptable to all Continental countries, Great Britain included, would have a far reaching effect on trade and commerce between them. It is evident, from an earlier comparison* made by the lecturer, that the stress distribution in a cement briquette must be of a very complex character. The loads are applied very obliquely to the contour at four points, and the shape of the briquette is one which invites complexity. This is at once evident from the lines of principal stress in the British standard form Fig. 2 (*b*), in which the contact loads applied by the grips produces a complicated stress system which would be practically impossible to unravel except by experiment.

At the time of the experiments indicated above, it was not possible to measure the stress distribution completely, but an attempt was made to find the

Fig. 1. (*a*) LINES OF PRINCIPAL STRESS IN A TOOTH OF A SPUR WHEEL (*b*) CONTOUR STRESS IN THE SAME TOOTH.



stress difference ($p - q$) across the minimum and principal section, and thereby to fix the relation between the maximum stress there and the mean applied load, since at the contour q must be zero at every place untouched by the grips. The earlier measurements so made are shown in Fig. 2, and indicate that this maximum stress is about 1·75 times the value of the mean average stress across the section, while in the Continental form it apparently rises to about 1·95 times the mean stress.

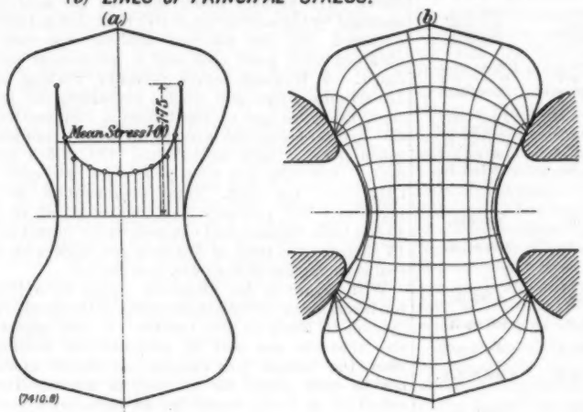
These measurements have been repeated and amplified recently, so that it is now possible to give a better idea of the actual stress systems at the central sections of each form, and Fig. 3 on page 757 shows the distribution obtained at the minimum sections of each briquette. As will readily be observed the distinctive feature of the distribution in each case is an extremely variable tension p across the section accompanied by a variable cross-stress q at right angles of considerable magnitude. In the British form, for example, with a load giving a mean average stress of 500 lb. per square inch, the highest value of p at the outer contour is 870 lb. per square inch, or 1·74 times the value of the mean stress, while it sinks to 405 lb. per square inch at the centre, or slightly more than 80 per cent. of the mean average value. In addition

* "The Distribution of Stress at the Minimum Section of a Cement Briquette." By E. G. Coker. International Association for Testing Materials, New York Congress, 1912.

to this stress there is a cross-stress which rises rapidly from a zero value at the contour to a value of about 235 lb. per square inch for the central six-tenths of the cross-section, so that the manner of loading and the form of the section calls into play a cross-stress of 47 per cent. of the mean average stress due to the pull. It is therefore seen that a member of this form is certainly not in pure tension, and the colour bands which are observed on the model indicate this quite clearly.

The standard French form of briquette shows much the same kind of distribution, but in a more pronounced form, owing to its different shape and especially to the circular indentations at the waist. In the actual test shown in Fig. 4, a mean average stress of 470 lb. per square inch develops a maximum tensional stress p of approximately 1,000 lb. per square inch, or 2·13 times the average stress, sinking to a minimum value at the centre of 300 lb. per square inch, that is 64 per cent. of the average value. In other experiments the ratio of the maximum stress p to the average value was found to be 2·05, 2·06 and 2·14, so that it appears very likely that this ratio is in the neighbourhood of 2·10, and therefore higher than the earlier value already quoted. The stress system described above is also accompanied by a cross-tensional stress, which rises to its highest value near the ends of the cross-section, and has a slightly less minimum value at the centre of about 260 lb. per square inch, or 55 per cent. of the average pull applied, and not a great deal less than the tensional pull across the section. A highly complex system of stress is therefore present at the cross-section for which the specimen is designed to fracture, and if anything like the same stress system prevails in the actual briquette, we cannot hope to learn anything very definite of the purely tensile properties of cement under such a complicated system of stresses in it. The lecturer pointed out that French engineers have long been alive to the fact that the distribution across the central section is far from uniform and that Durant Claye* had proposed an ingenious approximate solution based on some elementary principles, in which he obtained a curve of distribution with pronounced maximum values at the ends of the section.

Fig. 2. BRITISH STANDARD CEMENT BRIQUETTE.
(a) STRESS DIFFERENCE (p-q) AT CENTRAL SECTION.
(b) LINES OF PRINCIPAL STRESS.



Although these are the main features of the stress distribution at the waists of both British and French standard briquettes, it was pointed out that there is a good deal of work still to be done before any practical proposals can be adopted to obtain international uniformity in testing cement. It has yet to be shown that the stress distribution in a cement briquette is similar to that in a transparent model, and although it is always somewhat hazardous to make a prediction, yet it was considered there was some evidence both direct and indirect on which to base an opinion.

There is a very great probability that the stress in a cement briquette of considerable age is of exactly the same kind as experiments on transparent models show, since old cement has very perfect elastic properties. The fact that sound vibrations are transmitted very rapidly through cement partition walls and floors shows this, and in another direction it has been proved that such cement possesses very perfect thermo-elastic properties.* This latter property is not, however, possessed, or only imperfectly so, by cement which has been recently moulded, so that so far as this evidence can be taken into account it points to the conclusion that briquettes tested at the end of a week and a month, as is sometimes provided for in standard specifications, will not be under exactly the same type of stress as transparent models show. They are most probably in a semi-elastic condition in which, as all the evidence we possess indicates, the stress distribution is less variable than in the purely elastic state, so that any provisions found necessary from experiments on elastic bodies will more than cover the requirements sought. The older the briquette the more nearly the stress distribution approximates to that of the elastic condition of the transparent model. The chief bar, however, to uniformity appears to be in the varying shapes of the briquettes themselves, but the lecturer considered that it was not impossible to devise a simple means whereby this difficulty could be overcome without the necessity of a wholesale scrapping of existing testing machinery. Briefly, his proposal is to examine how far uniformity of testing can be obtained by maintaining in every case the existing forms of the ends, and lengthening the central part by the addition of a parallel part of the least possible length which will satisfy the condition that the stress in that part is a uniform tension. Thus, if the British standard briquette is taken, and a definite parallel length, T, is introduced, as shown in Fig. 5, the part in pure tension is at once defined by the zero isoclinics as indicated.

Fig. 3. BRITISH STANDARD CEMENT BRIQUETTE SHOWING THE DISTRIBUTION OF NORMAL STRESS p AT THE CENTRAL CROSS SECTION & ALSO THE CROSS STRESS q.

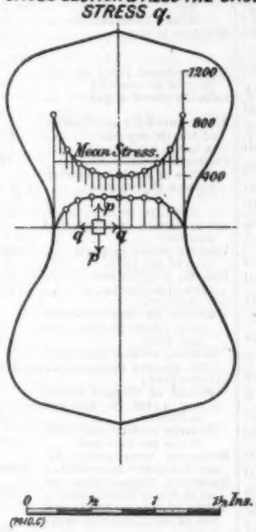
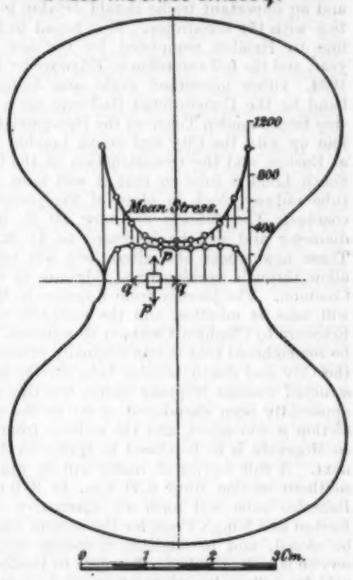


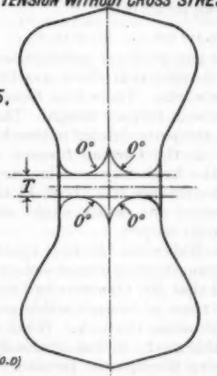
Fig. 4. FRENCH STANDARD CEMENT BRIQUETTE SHOWING THE DISTRIBUTION OF NORMAL STRESS p AT THE CENTRAL CROSS SECTION & ALSO THE CROSS STRESS q.



Having established this length T by experiment, it is a simple matter to make the length in pure tension any quantity considered desirable, and this need only be a small fraction of an inch. Further experiment will then be necessary to find in the cement briquette the stress distribution at the waist at various ages, and also to adjust the leading-in curves in such a fashion as to prevent stress concentration along them. It seems probable, if it can be established by measurements that there is uniformity of lateral contraction under load in each type of briquette lengthened in this way, that it will be generally accepted that uniform tension exists at these central cross sections. This has already been found to be the case in a model of the shape shown in Fig. 5. Thus it would only be necessary to alter the moulds now in use to obtain not only uniformity in the comparison of results, but also a real tension test of cement, which these experiments give some reason to believe has never yet been attained under existing conditions, owing to the variable tension at the waist, and the want of correspondence of this variability in briquettes of different patterns.

BRITISH FORM OF CEMENT BRIQUETTE MODIFIED TO GIVE A LENGTH 'T' IN UNIFORM TENSION WITHOUT CROSS STRESS.

Fig. 5.



NOTE.

UNDERGROUND RAILWAY EXTENSIONS.

WHAT the limit may be to the possible extension of the suburbs and outer suburbs of London it is not possible to say, but apparently as yet there is no sign of any check in the outward flow of population. The number of passengers using Golders Green station has increased from 1,600,000 a year in 1908 to nearly 12,000,000 a year now, while the increase in population of the district has been 67,000 in twenty years. Figures like these cannot be quoted for every extra-London area, and the growth in this particular case may unquestionably largely be attributed to travel facilities which have been provided by the London Electric Railway Company. A similar type of development is to be seen in the area served by the Baker Street and Harrow line as a result of the service provided by

* *Annales des Ponts et Chaussees.* Tome 9, serie 7, June, 1895.

* "The Relation of Thermal Change to Tension and Compression Stress," by E. G. Coker and C. M. McKergow. Transactions, Royal Society of Canada, 1904.

the Metropolitan Company. The Golders Green line is now to be extended to Edgware through Hendon, and a considerable movement of population may be expected in due course to follow it. The district tapped is at present served by two steam railways, but no very frequent service such as that which is rendered possible by electrification is at present given. The extension should lead to very extensive developments, particularly as the whole Golders Green neighbourhood has been developed in an attractive way. The ceremony of cutting the first sod of the new line was carried out by Sir Philip Lloyd-Graeme on Monday last. The new line will be 4·68 miles long, and there will be four intermediate stations between Golders Green and Edgware. One of these will be situated at Hendon, and an important traffic should develop in connection with the aerodrome. It is hoped to have the line to Hendon completed by October of next year, and the full extension to Edgware by January, 1924. Other important works also being put in hand by the Underground Railways are a connection from Camden Town on the Hampstead tube to join up with the City and South London Railway at Euston, and the reconstruction of the City and South London tube so that it will take ordinary tube railway stock in place of the present small coaches. The tunnels are now 10 ft. 6 in. in diameter and will be increased to 11 ft. 8¾ in. These new works and alterations will ultimately allow through working from Edgware to Clapham Common. The journey from Edgware to Moorgate will take 34 minutes, and the complete run from Edgware to Clapham Common 49 minutes. It will be remembered that it was originally proposed that the City and South London tube should be reconstructed without stopping traffic, but this idea has apparently been abandoned as far as the northern section is concerned, and the railway from Euston to Moorgate is to be closed to traffic on August 9 next. A full service of trains will be run on the southern section from 6.30 a.m. to 8 p.m. The Bakerloo tube will form an alternative route to Euston and King's Cross for the section which is to be closed, and in addition a special motor 'bus service is to be run from Moorgate to Euston. The vehicles will make intermediate stops only at Old Street, City Road, Angel and King's Cross.

THE IRON AND STEEL INSTITUTE.

British Siemens Furnace Practice.

At the annual meeting of this Institute held in London in May last it was found impossible to complete the discussion on the important paper by Mr. Fred Clements on "British Siemens Furnace Practice," and it was therefore arranged that an adjourned meeting should be called for the purpose. This meeting was held on Tuesday last, the 13th inst., in the Mappin Hall of Sheffield University, which was put at the disposal of the Institute by the Vice-Chancellor. We reprinted Mr. Clements' paper in full in our issue of May 12th last, page 573, and published at the same time (see page 593) the discussion which took place in London.

After the members had been welcomed to Sheffield University by Dr. Cecil Desch, who expressed the regrets of the Vice-Chancellor that he was unable to be present, the Chairman, Mr. E. H. Saniter reminded the meeting of the circumstances under which the discussion had been adjourned, and asked the author to give a brief summary of his paper for the benefit of those present. This he did, emphasising the points that only about 17 per cent. of the heat of the fuel was at present usefully employed in melting, and that progress lay in the direction of getting a higher temperature in the bath of the furnace.

The discussion was opened by Dr. T. Baker, who remarked that in the past the construction of open-hearth furnaces had been governed to a great extent by the rule of thumb, and had generally consisted in copying other furnaces which had given good results, and making such slight alterations as suggested themselves. Investigations such as those of the author put the matter on a much more satisfactory basis. About the year 1909 Mayer published the results of a similar investigation as one of the Rothe Erde furnaces. This was a 30-ton basic furnace working with a charge of about 73 per cent. scrap and brought out regularly 34 to 35 tons every 6 hours with a coal consumption of 5 cwt. per ton. The following table gave the comparison between the 60-ton Pargate furnace and the 35-ton Rothe Erde furnace.

	Clements' Park Gate.	Mayer. Rothe Erde.
Capacity of furnace ..	60 tons	35 tons
Analysis of coal (dry) ..	C = 77·53	C = 80·92
	H = 5·45	H = 4·92
	S = 1·33	S = 1·00
	N = 0·98	N = 1·66
	O = 10·37	O = 6·02
	Ash = 4·34	Ash = 5·50
	100·00	100·02
Net carbon gasified per 100 lb. coal	73·58 lb.	73·3 lb
Analysis of gas (dry) ..	By Vol. By Wt.	By Vol. By Wt.
CO_2	10·2 17·3	5·9 10·5
CO	19·0 20·6	23·7 26·9
H_2	12·5 0·96	16·1 1·31
CH_4	3·9 2·40	0·9 0·58
N_2	54·4 58·74	53·25 60·50
Heavy hydrocarbons ..	— —	0·15 0·17
Moisture in gas	6·06 per cent. 4·56 per cent.	7·5 per cent. 5·5 per cent.
Gas produced (dry) per 100 lb. coal as received ..	480 lb.	491 lb.
Calorific power of gas ..	—	1,121·9 C.H.U. (1,154·2) C.H.U.
Air required for combustion of 100 lb. dry gas ..	126·6 lb.	136·6 lb.
Gas burnt per minute ..	171·0 lb.	257·3 lb.
Products of combustion ..	447·4 lb.	598·2 lb.
Analysis of products of combustion (by volume) ..	CO_2 = 15·1 O = 4·1 N = 80·8	CO_2 = 16·2 O = 1·4 N = 92·4
Air in excess of theoretical quantity	22·9 per cent.	7 per cent.
Velocity of gas in ports ..	139·8 f.p.s.	188 f.p.s.
Area of gas ports ..	2 sq. ft.	1·97 sq. ft.
Velocity of air in ports ..	43·1 f.p.s.	87 f.p.s.
Area of air ports	12 sq. ft.	5·06 sq. ft.
Gas checkers : Weight of checker brick per 1,000 lb. gas per half-hour	7,685 lb.	4,829 lb.
Heating surface per 1,000 lb. gas per half-hour ..	671 sq. ft.	483 sq. ft.
Air checkers : Weight of checker bricks per 1,000 lb. air per half-hour	5,869 lb.	4,763 lb.
Heating surface per 1,000 lb. air per half-hour ..	512 sq. ft.	460 sq. ft.
Maximum temperature by gas in top of regenerator ..	1,108 deg. C.	1,300 deg. C.
Maximum temperature of air in top of regenerator ..	1,304 deg. C.	1,400 deg. C.
Weight of checker bricks per ton of steel (gas regenerator)	884 lb.	1,062 lb.
Weight of checker bricks per ton of steel (air regenerator)	1,304 lb.	1,391 lb.
Output of furnace	60 tons in 12 hours	35 tons every 6 hours
Coal consumption per ton of ingots	4·5 cwt.	5 cwt.
Surface of bath, per ton ..	5·95 sq. ft.	6·46 sq. ft.

So far as gas producer practice was concerned, Dr. Baker thought that there was little difference between the works. There was, however, considerable difference in furnace design. The gas and air velocities in the ports differed noticeably, indeed the air velocity in the German furnace was twice as great as in the English one. The gas consumption of the smaller furnace was about 1½ times as great as for the larger one, which might account for its somewhat larger output.

Mr. H. M. Ridge was the next speaker. Referring to a diagram showing a cross section of a furnace, he remarked that Mr. Clements had said that there was a large mass of incombustible gas in the top of the furnace under the arch. What was the composition of this gas? It was obviously not that of the gas passing through the furnace. It might be water vapour or hydrogen and the question might be investigated with advantage. Possibly the attack on the arches of furnaces might be due to an accumulation of water vapour there. The speaker would like to see the gas sampled at every inch downward from the crown of the furnace. The composition of the stagnant gas would be influenced by the velocity of the gases through the furnace. In the very long American copper smelting furnaces segregation of the gases had been observed. Radiation from the arch could not take place through flame or smoky gas. The speaker recommended the desirability of reducing the height of the arch, so that there should be no space for stagnant gas. The springing of the arch should be as low down as possible, it should spring from the top of the door opening. Mr. Clements' proposed height of furnace was 6 ft.; this could be reduced to 3 ft. 4 in. by replacing the stagnant gas by brickwork. It was possible to use specially elongated arch bricks, which would give a flat bottom to the arch, a design which had been patented by the speaker. Arches constructed in this manner had given absolute satisfaction. The loss of heat in the waste gases was an item which must certainly be reduced. Preheating the air would assist as it would increase the regenerator efficiency.

Mr. A. V. Kemp thought that the most startling figure in Mr. Clements' paper was the low efficiency of 16·98 per cent., which indeed was higher than the average of present practice. The low efficiency was due to the enormous quantity of nitrogen which diluted the gas. It was possible that matters might be improved by enriching the air going to the furnace, with oxygen, or using oxygen and steam in the producers. It was hardly fair to take as a basis for estimating the heat losses, the losses during the half hour of an individual charge, an average over two or three complete charges, or over a week's run would be better. Waste heat boilers should be fitted to open-hearth furnaces of present-day design. The evaporation obtained with a hot-metal-charged basic furnace, fitted with Babcock and Wilcox boilers was as high as 3 lbs. of water for every pound of coal gasified in the producer. The speaker noted that the gas analysis assumed by the author was better than that actually obtained, but the assumed analysis was easily obtained with good coal and a mechanical producer. A Wellman-Seaver producer working on Lanarkshire dross and singles containing 15 per cent. ash gave gas of the following composition, the figures being the average of hourly samples taken over a three weeks' run. $CO_2 = 5·3$ per cent.; CO = 28 per cent.; H = 14 per cent.; $CH_4 = 3·7$ per cent. Total combustibles 45·7 per cent. The producer was coupled direct to a 40-ton basic furnace, cold charged, which turned out 15 charges or a total of 573 tons per week with a coal consumption of 5·4 cwts. coal per ton.

With regard to Mr. Clements' design for a 100-ton furnace, one or two details would, in the speaker's opinion be likely to give trouble. It was imperative that the gas port be accessible for fettling when the furnace was running, so that it could not be built inside the air port as shown. The reduction in width would be all right on a new furnace but would give trouble after some weeks by blocking up. With the high temperatures employed on the regenerator, silica bricks would have to be employed and a 2½ in. silica brick would not be strong enough to carry the weight of the deep checkers. Mr. Kemp then gave figures comparing the proportion of some 75 ton furnaces he had built a few years ago, with the author's design, and commented on the points of difference.

He quite agreed with the author's remarks about reversing valves, particularly the gas valve which automatically cut off the gas at reversal so that no escape to the chimney was possible. This effected a considerable economy which was often overlooked by furnace designers. Regularity of reversal was of great importance and can easily be arranged for, but provision must be made for operation by hand should the furnace conditions require an alteration in the period. The fuel consumption of 3 cwts. per ton of steel, estimated by the author, should be obtainable with a quick and efficient furnace and hot metal charging. The figure of 4 cwts. per ton, was obtained on the speaker's design of 75 ton furnace with cold charging, and should be reduced by 25 per cent. by working hot metal in conjunction with a mixer.

Mr. Percy Longmuir spoke very briefly, congratulating the author on the excellence of the paper.

Mr. H. Brearley remarked that the open-hearth furnace had to possess a certain qualification which was considered desirable by a certain amateur in a business he wanted to purchase "It must be able to stand a lot of mismanagement." The man who set out to design open-hearth furnaces must bear this feature in mind. By now there ought to be sufficient experience to enable the radiation losses to be forecasted with reasonable certainty. When the furnace walls wore very thin the losses must be enormous. Could the author give figures comparing an old furnace, with itself when new, and were the pounds of coal used per ton of steel distinctly greater when the furnace was old. There should be some definition of exactly what was

included in the terms "regenerator" and "checkers." The speaker had had experience of a furnace abroad with a very long flue. The regenerator only got red hot, but the furnace worked all right as the flue surface did the work of regeneration. One notices in the paper some very marked differences between the basin furnaces illustrated and yet they all did good work. Sometimes a very minor alteration would make a bad furnace into a good one. It was therefore very difficult to say upon what factors excellence really depended. It would be an excellent thing if some one would bring before the Institute a set of designs of furnaces which have done badly and point out the reasons why they had done so. The author had referred to recent improvements in silica bricks, but the speaker had asked users of these bricks what the improvements were and had been told that none had been noticed.

Mr. E. B. Christmas pointed out that the author's design for a 100-ton furnace contained valves which necessitated the incoming gas and air, and also the outgoing gas, passing through four different right-angle bends. Such bends involved an unnecessary loss of pressure and draught. Furthermore it was shown in the paper that the gases dropped in temperature in passing through the valves. It would therefore seem better to adopt straight-through valves. Most American works were now using straight-through water-cooled damper valves working against a water-cooled seating. Right-angle bends caused a drop of 40 per cent. to 60 per cent. of the chimney draught, so that if the chimney draught were 1½ in., the pull on the regenerator would be only ¾ in. Preventing the loss would enable the checkers to be run longer without cleaning out. It was often held that the water-cooling of the refractories of a furnace must necessarily extract a lot of heat, but this the speaker denied. With the ordinary open-hearth design it was unpleasant to walk within 10 ft. of the furnace fronts, so great was the radiation. With water-cooled doors and door frames one could lean up against the doors with comfort.

The speaker gave figures relating to water-cooling as practised at the Gary Works, near Chicago. On each of their 45 furnaces, 15 ft. 3 in. by 39 ft., tapping 90 long tons to 93 long tons and averaging 15 heats per week, they have five Knox doors, which use 75,000 U.S. gallons and 5 Knox door frames which use 225,000 U.S. gallons of water per 24 hours. Less water might be used. Mr. Christmas argued that the use of water-cooled doors effected a saving equivalent to 46 lb. of coal per ton of steel made, on account of the suppression of radiation. They also made operation more comfortable for the men.

Mr. Kilby remarked that although there was nothing exceptional in the author's producer, or in the quality of gas made, or in the period of charge for the furnace, nevertheless a coal consumption was obtained which was remarkably low. The increase in fuel cost had made economy vital to the industry. Mr. Clements' system of compiling data was invaluable and applicable to any open-hearth plant. Was the figure of 4·5 cwt. of coal per ton an average of the working of the furnace or only an example of its best performance? Similarly were the figures for other firms taken over a long period and did they relate to a battery of furnaces? Mr. Clements took a three-charge period for his detailed thermal research and showed a consumption of 3·7 cwt. per ton. This was extremely good, but equally good results had been achieved in other works for similar periods. A certain 60-ton furnace tapped 866 ingots, using all cold stock. The average coal consumption worked out to 4·5 cwt. for the week, and for certain periods in the week it was as low as 3·2 cwt. The quickest heat was 7·75 hours from commencing to charge to tapping. The overall time from tap to tap was 8·5 hours. Referring to the proposed design for the 100-ton furnace, Mr. Clements gave a chimney height of 200 ft., but did not mention the diameter. His views on this would be interesting. It was also an open question whether a 100-ton furnace was a more suitable size economically than the 60-ton to 70-ton type. Mr. Clements was very hopeful as to the economy of his proposed furnace. On gas-fired regenerating heating furnaces it required from 2½ cwt. to 4 cwt. of coal to heat the ingots to rolling temperature. Taking 2 cwt. as the lowest consumption for a gas-fired soaker plant, where the chimney temperature was no greater than that of the open-hearth chimney, and where the efficiency was at least equal to ordinary open-hearth practices, it appeared to be expecting rather a lot to hope to liquify and refine the charge with the coal consumption forecasted by the author.

Dr. C. H. Desch considered Mr. Clements' paper to be the most useful contribution yet made on the subject of steel furnaces, as the information was collected and presented in a systematic way. If progress was to be made in open-hearth work more attention must be given to the quality of the gas used, as this was of the highest importance. A certain amount of investigation had been carried out in Russia on the question of the flow of gas through furnaces. The flow was of a turbulent nature, and calculations were therefore difficult, so that models such as those made by Mr. Clements were useful to illustrate what was happening.

Mr. E. C. Ibbotson inquired whether there was any advantage in mechanical producers over the old fixed producers of the Wilson type. Some firms still retained their faith in the fixed producer. The Kerperley mechanical producer was good for use with the bad fuel in Austria, but in Great Britain, where the fuel was good, the case might be different. He would welcome the opinion of others on the point.

Mr. Methley, dealing with the remarks of the last speaker, said that the question of automatic *versus* hand-fed producers was largely a question of the class of fuel used. The mechanical producer would burn dross, but could not burn good coal so well as a fixed producer operated by a good man. With regard to Mr. Clements' results, was it not possible that he might have got more heats per week if he had used rather more coal in the producer, a procedure which would still further reduce the coal used per ton of ingots made.

Mr. A. Lindsay Forster said he would confine his remarks to the question of recuperation. The author had spoken as if much more was to be done in the furnace by getting a little more heat into it. Could not the low grade waste heat be taken advantage of more fully than at present for working waste heat boilers to make steam for the producers. This would be making a more efficient use of it than in regenerator checkers. Another question was whether the furnaces which operated with high velocities of gas and air in the checkers gave the best results. If one tried to arrange the furnaces described in the paper in order of merit, one could draw definite conclusions as to what produced the merit. Taking the coal used per unit of output as a figure of merit, the Parkgate furnace had the lowest consumption, yet it had not the highest temperature. Nor could any outstanding feature of the regenerators be correlated with economy. One could not put his finger on any single feature of any of the eight furnaces and say that results demonstrated that it was good. Was it possible that any of the discrepancies in the temperatures observed were due to the different methods employed by observers. The speaker himself did not worry about discrepancies of 20 deg., 30 deg., or even 40 deg. between different observations, and even at times he was satisfied when the difference amounted to as much as 100 deg. C. Pyrometry was an exceedingly difficult art. Taking some figures given in the paper, the speaker said that they indicated that as much regeneration took place in two lengths of flue as in the whole of the regenerators. Perhaps this was to be explained by the fact that the pyrometry wanted looking into. Some people tried to measure the temperature of gas moving along between red-hot walls by pushing a thermometer into it. The radiation from the walls would entirely vitiate the result, and the procedure was as foolish as putting a thermometer in the sun to measure the temperature of the atmosphere. The author had advocated the adoption of a gas speed of 20 ft. per sec. through the checkers. What was the reason for recommending this figure? A speed of 14 ft. per sec. appeared to be the highest attained in any of the checkers with which Mr. Clements had dealt in the paper.

Mr. Clements here interposed to explain that the temperatures to which Mr. Forster had referred were taken when the furnaces were not in operation, so that there was no gas flow. The temperatures were those of the walls, and not of the gas.

Dr. T. Swinden, after referring to the monumental character of the paper, regretted that the author had relied on data published in Germany in 1914 for his table of the heat characteristics of refractories. These figures played an important part in the calculations, and, unfortunately, many of them were of doubtful accuracy. The thermal conductivity of magnesite brick and the specific gravity of silica brick were both wrongly given, and the data, indeed, were misleading as a whole. Everyone who had to make steel with cold-charged material, of the quality commercially available, would envy Parkgate, where such excellent hot metal was at hand, and might feel after all that, with such metal containing only 1·5 per cent. to 0·75 per cent. of silicon and 0·03 per cent. to 0·05 per cent. of sulphur, along with such excellent scrap, even 4·5 cwt. of coal to the ton was not lower than might reasonably be expected. Could Mr. Clements state the reason for reversing the positions of the gas and air regenerators in his proposed furnace, as compared with existing practice. Was there any reason why the greater simplicity in the structure of the flues to be obtained by putting the air chambers outside should not be adopted, and if there was none why were the air chambers generally put inside?

The Chairman, Mr. E. H. Saniter, said that there was no doubt that the heat conductivity of magnesite brick was greater than that of silica brick, and it was common experience that the outside of magnesite bricks got hotter than the outside of silica bricks. Much of the loss of heat from a furnace was due to the necessity of fettling after each charge. Referring to the Parkgate results, the speaker remarked that when one had molten iron with only 0·25 per cent. of silicon, the conditions were good for economy, as both coal and limestone were saved. The outstanding feature of the Parkgate results was the low fuel consumption obtained in spite of poor gas and a small output. What was the real reason why, under such conditions, steel could be produced for only 4·5 cwt. of coal per ton?

The author, in replying to the discussion, said that the object of the paper was to correlate theory with observed facts. So many observed facts were misunderstood and misinterpreted unless examined in the light of established theory. During the London discussion some of the graphs given in his paper had been called into question. Since that time he had had other sets of observations recorded, and these substantially confirmed the previous observations. The speaker who had criticised the heat balance sheet could not have read the paper closely. The point had also been raised as to whether the carbon in the charge was burnt to CO or to CO_2. It has been assumed in the paper that it was burnt to CO, for the carbon left the bath in this combination, and the further burning to CO_2 took place afterwards. The radiation losses in a furnace varied with the state of the charge in the furnace, and consequently no figure could be usefully given except over short periods of time. It was difficult to put one's finger on any definite reason why the Parkgate results were much better than those generally attained in steel works. It was on record that a ton of steel for 4·5 cwt. of coal had been produced as a twelvemonth's average, and no doubt the figure would be the same for the past five years. The only reasons which could be given were that the furnaces were well designed and well maintained. The roofs were not allowed to get thin, and no jets of flame were to be seen coming from them. The human element was also very important. It was fashionable to decry the British workman, but Mr. Clements' experience was that the average workman was a good type of man, who tried to co-operate with the management in getting the results required.

The author illustrated his contention as to the paramount importance of furnace temperature by considering three cases. In each case it was assumed that the calorific value of the gas was the same and that 1,450 deg. C. was the melting

temperature of the bath. In the first case a regeneration of 500 deg. C. was assumed. This would give a flame temperature of 1,431 deg. C. and with a given amount of gas passing, 3,638 C.H.U. would be liberated per second in the furnace. Nevertheless the charge would never reach melting temperature. In the second case with 1,000 degrees regeneration, the flame temperature would be 1,746 deg. C. and 4,743 C.H.U. would be generated per second. Of the latter, 988 C.H.U. would be in excess of the heat required for melting. In the third case, with 1,500 deg. C. regeneration the flame temperature would be 2,031 deg. C. and 5,563 C.H.U. would be liberated, of which 1,808 C.H.U. would be in excess of the heat required for melting. It was therefore evident that by regenerating to 1,500 deg. C., an increase of temperature of 16·3 per cent. and an increase in effective heat of 83 per cent. were obtained, as compared with a regeneration to 500 deg. C. only. In this fact lay the whole secret of the future development of the Siemens furnace.

With regard to water-cooled furnace doors advocated by Mr. Christmas, it might be mentioned that other people, including the speaker, had been to America and noted American practice. Mr. Clements had no hide-bound ideas on the subject. If one could get on satisfactorily without water-cooling it was better to be without it. At the Chicago plant mentioned by Mr. Christmas they had an indefinite amount of good water for cooling, but in Sheffield there was only the Don, which wasn't much good for anything when the other people had done with it. A cheap and good water supply was really the dominating consideration with regard to water cooling.

The high temperatures which were so desirable in furnaces could only be obtained by regeneration, and the efficiency of regeneration had to be raised. People nowadays went in for big checkers, which was wrong in Mr. Clements' opinion. They forgot the fact that there was only a limited amount of heat going out in the waste gases. If the checkers were too massive the brickwork could not be heated up to the requisite temperature by the gas available. One had to burn more fuel in the producers merely to heat up the brickwork, which was obviously wrong. A high velocity through the checkers was advisable because only thus could a rapid heat transference be brought about, and the time element was an important one. It was only the first inch in the thickness of the brickwork which could be counted on to absorb and give up heat, and bricks therefore which were more than 2 in. thick might be regarded as ineffective. It would be noted that the Brymbo furnace, which had the highest velocity through the checkers had the highest regeneration temperature. Moreover, the higher the velocity through the checkers the less the dust deposited, for the weight of the particles carried along by an air stream varied in proportion to the cube of the velocity of the air.

As regarded the height of the checkers, the increase of height also increased the "chimney effect" of the hot checkers on the incoming air, and this to a great extent compensated for the extra resistance. When gas was going out through high checkers, a high chimney was necessary to give sufficient draught. At the Brymbo works, the checkers were only spaced at 2¼ in. apart, which was very near the 2 in. advocated by the author. It had been suggested that very high regenerative temperatures might dissociate the producer gas and cause trouble that way. Mr. Clements, however, had taken samples of gas mixed with very hot air and had found no evidence of the dissociation of the CH_4 He had also experimented with CH_4 in silica tubes at a temperature of 900 deg. C., and dissociation under such conditions only took place to the extent of 12·3 per cent. In practice where the CH_4 was flooded with other gases and kept away from the hot firebricks very largely, it was doubtful whether any appreciable decomposition took place.

In conclusion, Mr. Clements said he had no hesitation whatever in saying that a fuel consumption of 3 cwt. per ton of steel was possible, and he expected to do even better than this. Ordinary practice soon ought to be down to 4 cwt. per ton. If we could save 2 cwt. of coal per ton of steel, it would be a good thing both for the steel industry and for the country, as it would mean a saving of a million tons of coal per annum.

Votes of thanks having been accorded to the author for his paper and to the University authorities for the use of the Mappin Hall, the meeting terminated.

INDUSTRIAL NOTES.

THE Spanish Inquisition was defensible only on the hypothesis that belief was wholly a matter of volition. Strong arguments in favour of such a thesis might well be collected from the speeches of labour leaders. For example, Mr. Smillie in an address at Clydebank on the 8th inst. professed to believe not merely the absurdity that the miners, engineers and shipbuilders have in the recent disputes been defeated by organised capital, but also in the super-absurdity that "the lock-out of the miners was not merely a question of the mine-owners locking out their own hands, but a plot in which members of the Government were engaged, and the British industries were behind the plot." Organised capital would, however, have nearly as much to gain as the workman by a continuance of the conditions, which held during the war. The nation then required certain goods at all costs, and those who supplied them demanded very high rates for their services. For each penny of excess profits obtained by the capitalist, however, the workmen took an excess profit of sixpence or a shilling, and unlike the capitalist they were not mulcted some 60 per cent. to 80 per cent. of these excess profits by special taxation. The defeats suffered by the miners and engineers' unions have not been brought about by organised capital, but by the unorganised consumers, who have found themselves unable to pay the prices demanded and thus restricted their purchases to the minimum. Most of us are worse off than before the war, and accept it as part of the price we have had to pay for securing our right to live our own lives free from Zabernism and Junkerism. It is only organised labour, and particularly that part of it that did a minimum of the work at the front, which claims that it should not be called upon to bear its share of the general burden.

Mr. Henry Gosling, speaking on the same date, was almost equally as funny as Mr. Smillie. He complained that the big shipowners "had built new ships and bought new machinery." The real trouble has, however, been a dearth of orders for new ships and machinery. When the war broke out, we owed our salvation to the 20,000,000 tons of merchant shipping which had been built up because clever men had been able to make relatively high profits in the shipping trade. If they had not made these profits, neither ships nor machinery would have been constructed. Moreover, had the high profits been distributed to the men they employed they would for the most part have been dissipated in one form or another of self-indulgence. When a manufacturer makes a fortune he invests it in extensions to his works, thus providing well-paid employment for additional men. At pre-war prices each £200 thus invested provided, on the average, wages for one more workman. Co-operative societies, it is important to bear in mind, have never founded a new industry or effected any important improvement in methods of distribution. The general well-being of the country in normal times, has thus unquestionably been due to the much denounced capitalist.

The aftermath of the shameless profiteering by the pitmen during the war, and the senseless strike of last year, has not yet been fully garnered, and many of our coal-mining areas are accordingly far from prosperous. The situation has, of course, been aggravated by the unwisdom of the engineers and of certain sections of the men engaged in our textile industries. Nevertheless, Mr. James Tonge, who speaks with authority on the Lancashire area appears to be hopeful as to the future. One great trouble at present is the relatively high cost of maintenance charges as compared with output. This is partly attributable to the war during which repairs had to be postponed. Still Mr. Tonge is convinced that when the cotton and engineering trades are once more flourishing the coal industry will again be able to hold up its head with the rest of the country, for the Lancashire coalfields have the advantage of being adjacent to large industrial areas, which more than compensate for some of their disadvantages. Mr. Tonge believes that there is much in store for the Lancashire collier, and that not only will his wages be increased, but that the price of coal to the consumer will be considerably reduced.

The May price of west coast hematite pig-iron rose by 11*d.* to 4*l.* 19*s.* 5*d.* per ton. Blast furnacemen's wages accordingly rise 1¼ per cent. to 36¾ per cent. above the standard, the first increase for 18 months.

Notices to cease work were served last Monday upon the operatives in a number of provincial newspaper and general printing offices. The notices expire on June 24, and were tendered by members of the Master Printers' Federation and Newspaper Society in support of a proposal that a wage reduction of 15*s.* weekly for men, and 7*s.* 6*d.* weekly for women, shall take effect on that date. In cases where notices had not been tendered the Typographical Association asked for an undertaking in writing from the employers that no wage reduction should take effect during the present year. They followed this by handing in 14 days' notice to cease work in establishments where the undertaking was not forthcoming. Evidently the leaders, like the late Prussian General Staff, are firm believers in the principle of the preventive war.

After a cessation of work, which has extended over 13 weeks, the members of the Amalgamated Society of Engineers have accepted the memorandum of the employers' proposals. The ballot figures were 75,478 for acceptance and 39,433 against. The direct loss in wages and in the cessation of output runs to a very large figure, which will be greatly increased by the indirect losses. If, however, as judging from past experience seems probable, this contest may be a prelude to a long period of peace, the net result may in the end be not disadvantageous to the industry. The threat of constant disputes over trivial points, causes the loss of contracts to countries where the necessity of pleading the strike clause in excuse for delays in delivery seldom arises, and where shop stewards do not give orders that machines are to be run at the lowest speeds. An abatement of these heavy handicaps on the British engineering industries, may thus prove to have been purchased relatively cheaply. On the overtime question, Sir William Mackenzie, in his report to the Ministry of Labour, substantially accepted the contention of the employers, that they were in most cases alone in a position to judge as to its necessity. Nevertheless there have been undoubted and unnecessary hardships at times. Men may be told late in the afternoon that they will be required to work overtime that night, and thus have no opportunity of making arrangements for a meal. In one case where this happened on a breakdown job the foreman on his own responsibility sent out for some provisions, with the result that the "office" surcharged him with the amount expended. Youths and young men, again, may have their studies at evening classes interrupted by being called on to work overtime, and though most firms, on appeal, will make arrangements to let such students off, this often involves them being put on to a worse class of work. Older men seldom attend classes, so in their case this particular objection hardly arises.

The ballot of the foundry workers has also shown a majority in favour of resuming work. This result was somewhat unexpected, and is the more welcome accordingly as it affords evidence that the rank and file are at length recognising the actual state of affairs. It is probable that in these conditions the boiler makers will also come into line, in spite of the adverse ballot already taken. The federations have recommended, in view of the agreement, that as many men as possible be found work at once. In the heavy engineering trades, however, the immediate outlook is not too bright, but there is a large demand for textile machinery. High production costs are still a serious handicap, but with the greater freedom now assured them the better-managed firms will be in a position to effect reforms which may materially diminish costs without affecting rates of pay.

The publications branch of the Mining Association of Great Britain has issued the following statement: "It is generally admitted that miners' wages are at the present time low—in many districts at the minimum, or approaching it. But discussion of the matter in the press reveals a serious misunderstanding of what is meant by the minimum, with the result that misleading comparisons have been made and exaggerated inferences drawn. The minimum is fixed by the agreement, which is now in force, at standard wages, plus 20 per cent. thereof. Standard wages, it appears, are commonly thought to be the wages paid in 1914, so that the minimum under the agreement is erroneously calculated as the 1914 wage, plus 20 per cent. There is, however, a notable difference between the actual wage of 1914 and the standard wage of to-day. The following figures are taken from returns furnished by over 95 per cent. of the total number of collieries: During April last the average earnings per shift per person, men and boys, amounted to 10*s.* 6½*d.* The aggregate wages bill at the collieries was 7,750,380*l.*, of which 5,682,400*l.* represented standard wages. By a simple sum we get a figure of 7*s.* 8½*d.*, representing the 'per shift' equivalent of standard wages. Now the actual wage per shift in June, 1914, was 6*s.* 5½*d.*, which is less than this year's standard by 1*s.* 3*d.* To

the higher figure must be added 20 per cent. to bring it up to the minimum. It thus appears that when wages are reduced to the minimum provided for by the agreement, they are, in effect, 42·97 per cent. above the 1914 level, and not 20 per cent. as has been stated."

NOTES ON SCREW THREAD TOLERANCES AS RECOMMENDED BY THE B.E.S.A.

TO THE EDITOR OF ENGINEERING.

SIR,—Arising out of correspondence on the above subject which appeared in your March issues, a firm of machine tool makers wrote me as a member of the Screw Thread Committee of the British Engineering Standards Association, and asked me, as a practical manufacturer, to give my opinion on the tolerances recommended by that Committee. On receipt of my reply they suggested that I should send it to you for publication, and it is on that account that I venture to trespass on your valuable space.

The Whitworth thread has been proved by various experiments to be as good a combination of shape of thread, spiral angle, and diameter, as can be obtained. As everyone knows, it consists of seven elements, viz., three diameters (major, minor and effective), three elements of shape (angle, radius at crest, and radius at root) and pitch.

It is only possible to get satisfaction out of the Whitworth combination provided the thread is perfect in each one of all the above elements at the same time, because all these elements of the thread on the bolt fit with equal clearance or lack of clearance to their corresponding element on the nut, *e.g.*, if the radius at the crest of the bolt thread is a little lobsided, the bolt will fit on the nut at this one spot only, and will be clear as regards all the other elements, provided the latter are perfect.

The controlling factor in the Whitworth thread is really the spiral angle or pitch, in exactly the same way as the controlling factor in a Morse taper socket is the angle of taper. The Morse taper socket is a straight cone, and the Whitworth thread is really a spiral wedge. Any hard spot in a Morse taper socket will render it liable to come loose, and similarly, any interference with the fit of a Whitworth thread on the tight side of the angle of the thread will cause the nut to work loose.

The Screw Thread Committee of the British Engineering Standards Association therefore decided to clear away any chance of interference with the thread fit on the major and minor diameter, and also on the radii of the thread shape at such diameters. They did this, not by altering the theoretical shape of the thread, but by increasing the tolerance at these points so that on the average there is less risk of interference at these points than on other points where the tolerances are not so large. This narrows the problem down to one of effective diameter, angle of thread flank, flatness of face on thread flank, and pitch of screw, or, in other words, the taper and surface of the spiral wedge.

In order to find out how much margin one had to play with in setting tolerances at this point, a series of experiments was made, starting with bolts and nuts having threads to the minimum clearances allowed in the tables, further samples being made with gradually increasing clearances until a clearance figure equal to half the depth of the thread was reached. On pulling these samples apart, it was found that the strength of a bolt and nut with half-thread engagement was considerably greater than anticipated. Speaking from memory, the reduction in strength for half engagement was of the order of 15 to 20 per cent.

A further series of experiments was made with full thread engagement, but reducing the length of the nut from one diameter downwards it was found that with a British Whitworth thread (I think it was Whitworth, not B.S.F.) the thread gave way before the body of the bolt up to 3½ threads engagement, but at four threads engagement and upwards the body of the bolt always broke without exception. This shows that the average Whitworth nut, one diameter long, is many times stronger as regards thread engagement than the bolt body, always assuming that the thread is well made and has not been damaged during assembly.

It was found impossible by theoretical experiments to get any information as regards liability of slackening off. However, my personal opinion is that a properly made screw thread bearing on the angles of the thread will not slacken off, except under intense vibration, when proper means for locking should be supplied.

In a recent discussion at a local engineering society a speaker deprecated the tolerances recommended by the British Engineering Standards Association and recommended gauging by major diameter, together with a condition that the bolt should be a spanner tight fit in the nut; the class of thread this speaker was asking for might be anything; it would certainly be doubtful as regards fit on effective diameter. The spanner tight feature is really supplied by means of a locking device which is inherent in the malformation of the thread, and would take the shape of some kind of obstruction on any of the seven elements. It would bite into the corresponding part of the bolt thread, and form a locking device practically as efficient as a set screw screwed up radially through the nut and tightened on to the bolt. Similarly, a half-stripped thread would also be spanner-tight, but would be perilously near collapse due to threads stripping.

It will be seen from the above that unless a screw thread is made either so deformed or distorted that it is a "spanner fit," or is made absolutely perfect in all its elements with no clearance, so that the nut wrings on to the bolt rather like a Johansson gauge, there must be a certain amount of slackness between the bolt and the nut; that is, if the flanks of the threads on the tight side are hard up against each other, there will be a clearance of half a thousandth upwards on the disengaged side of the thread. It makes no difference to the efficiency of the thread whether this clearance is half a thousandth or twenty thousandths, provided engagement is not reduced more than 10 per cent., bearing in mind that a reduction of 50 per cent. engagement alters the strength of the thread by about 15 per cent.

In order to demonstrate this point, a large selection of satisfactory articles, all of which had passed Government gauging, were cut in half and examined under a thread projector. The actual clearances existing in these samples of work were very considerably greater than those now recommended in the Report of the Standards Committee, the difference being that by the old method of Whitworth screw-gauge measuring, the clearance existed but the gauger had no knowledge of it, whereas, under the new shape of thread we have knowledge of the clearance, and take steps to ensure that it is kept within reasonable bounds.

Taking the report on B.S.F. threads from ¼ in. to 1 in., the minimum clearance between bolt and nut is two thousandths, which might, with the aid of a little dirt and oil, give a spanner fit, certainly a hand-tight fit, and the maximum clearance is from 12 thousandths to 14½ thousandths, the thread interference being from 80 thousandths to 128 thousandths. The maximum clearance expressed as a fraction of thread interference is therefore one-seventh on the ¼ in. size, one-eighth on the ½ in., and rather less than one-eighth on the 1 in. If one can ensure that no more than these clearances exist, the strength of the bolt is not appreciably altered. In actual fact, it will be found that the average operator will make his bolts as large as possible, leaving room for reduction, and his nuts as small as possible, leaving room for opening out, so that there is room to rectify rejected work. Theoretically, of course, this is wrong, but it is an observed fact in practical manufacture, especially where the operator controls the dimension of the finished work.

It is expected that on automatic work, where a more intelligent man sets up the tools, he will set up his dies to cut at the small end of the tolerance, and his taps to cut at the large end of the tolerance, so that as the die and taps wear, the bolt becomes larger and the nut becomes smaller.

Coming to the actual tolerances recommended on a ½-in. bolt, the total tolerance on an effective diameter is five thousandths. It was assumed that about half of this, say, two and a-half thousandths, would be absorbed by pitch error and error of angle, and the other two and a-half by difficulties met in getting the pure diametral dimension; or if you like to cut your diametral tolerance to nothing, all the five thousandths can go to pitch and angle, and *vice versa*.

It should be borne in mind that any error in pitch, plus or minus, or any error in angle, plus or minus, has a cumulative effect on the effective diameter of the screw. If again you divide the tolerance permitted in each section of this dimension in half, and allow one-half of the tolerance for setting up your machine, and the other half for wear on the tools, you have got to set your machine to work within a diameter tolerance of 1¼ thousandths, and allow 1¼ for wear or trouble. You have to set off another 1¼ for the cumulative pitch and shape errors in your diehead or tap, and leave another 1¼ either for dulling of edges, or for drag on your capstan head or tapping machine spindle, causing the pitch or thickness of thread to go wrong, due to the weight of the machine affecting the cut.

When looked at in this way, the tolerances allowed on, say ½ in., are reasonable, and you will find that the tolerances on every size are in proportion, with the exception of the smaller sizes, like one-quarter, where it was felt that a minimum tolerance anyhow was necessary for any work, whatever size, and if the *pro rata* tolerance for the size came below that minimum tolerance the minimum tolerance should be allowed.

There is a further point of view on small screws. Supposing you are making a thousand or two articles a week, such as electric meters, speedometers, or car dynamos, where there may be two or three dozen screws in each unit, the extra work involved in assembling 50,000 screws per week, which are either spanner-tight, handtight, or reasonably slack, might represent several pounds' worth of labour, and if the truth were really known, a more efficient job is produced by the reasonably slack fitting screw than by either of the two tighter grades, which may only be tight due to some imperfection in form causing an obstruction.

You will note from the report that the old Whitworth form, *i.e.*, theoretical dimension of the screw, coincides with the bolt dimensions of the effective diameter, the effective diameter of the nut being two-thousandths bigger in every case, as against, I believe, one-thousandth bigger under the old report. Although as a minimum nuts are two-thousandths bigger than the theoretical Whitworth size, and one-thousandth bigger than formerly, for all practical purposes the same screw gauges as before can be used for "go" gauges, and new plug gauges made when existing gauges are worn out. In either case an effective diameter "not go" gauge should be made preferably about two or three threads long, made to the "not go" end of the effective tolerance, and absolutely clear on major and minor diameters.

As nearly all screw work is produced by some mechanical means, it is near enough if one or two per cent. of a batch is measured by this means. For bolt work of a repetitive order, experience has proved that the projector method of gauging is much quicker and more effective than metallic screw gauges, provided quantity warrants setting the apparatus.

Such people, who for any special reason require to control the tightness of the fit of the bolt in the nut, can easily do this by arranging to analyse their products in accordance with the "grade and play" scheme referred to in the report—see columns 15 and 16 of Table II, and for definition of "grade and play" see Report No. 84 of 1918, dealing with B.S.F. Threads, where "Grade and Play" is fully dealt with in Appendix I, page 25.

I do not think it is a very practical scheme for measuring commercial bolts and nuts, but makers of taps and dies will probably find this of great use to them in classifying their tools by the grade of work produced, so as finally to decide which particular grade of tool is best adapted for any particular class of industry, or, possibly, which grade is right for standardising for all classes of industry.

I regret that I have had to make certain statements from memory in these notes, as time has not permitted a proper search through the files to enable proof to be available. The notes are not intended to be in any way an authoritative statement by an expert working on the subject, but only the impressions which arose in a manufacturer's mind when listening to real experts on the matter comparing the results of their experiments amongst themselves. It is hoped that, when read in this sense, it will be useful to other manufacturers in helping them to take the maximum advantage of the various reports compiled by the Screw Thread Committee of the British Engineering Standards Association.

I am, Yours truly,

A. H. STUBDEE.

English Electric Company, Limited,
Ordnance Works, Coventry.
May 25, 1922.

A NEW MOVE IN SCOTTISH WELFARE.—Whatever may be the shortcomings of welfare supervisors in shipyards, engineering establishments, and other public works in Scotland, apathy is certainly not one of them, judging from the progressive spirit shown by the Scottish Society of Welfare Supervisors. Their latest venture is the production of a national welfare magazine consisting of 40 pages, for distribution mainly among those engaged in public works in Scotland. It is appropriately called *The Compass*, and will be issued monthly at the price of one penny, the first number being issued on June 1. The aim of the magazine will be to co-ordinate so far as possible, the various welfare activities carried out in Scotland.

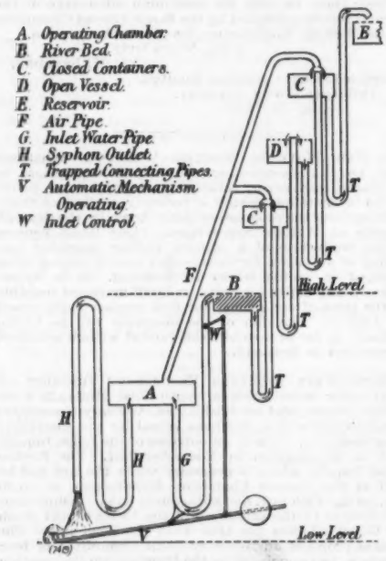
SOUTH-WEST MIDLANDS ELECTRICITY DISTRICT.—A draft order constituting a South-West Midlands Electricity District, and establishing an Advisory Committee in connection with it, has been issued by the Electricity Commissioners. This is an outcome of the Local Inquiry held in Birmingham in November last. The further Local Inquiry which is necessary under the Act will be held at the Council Chambers, Birmingham, at 10.30 a.m. on the 29th inst. and subsequent days. Objections in reference to the provisions of the Order should reach the Commissioners not later than the 22nd inst. The scheme proposes an Advisory Joint Committee of four members, two appointed by the Birmingham Corporation and two by Shropshire, Worcestershire and Staffordshire Electric Power Company. Two of the members shall be the chief engineers of the two authorities. Copies of the order giving details of the technical and administrative scheme may be obtained from the Secretary to the Electricity Commissioners, Gwydyr House, Whitehall, London, S.W. 1.

IRON ORE RESOURCES OF SOUTH AUSTRALIA.—The iron ore produced in South Australia in 1919 exceeded in value that of any other mineral product. Mr. R. Lockhart Jack, F.C.S., Deputy Government Geologist, reports that he has examined and described all the larger known bodies, and that many reputed to be of some magnitude have been found to be insignificant in size. The outstanding deposits are the Iron Knob and Iron Monarch, and the Iron Prince and Iron Baron in the Middleback Range, estimated to have ore resources above the level of the surrounding country of 133,000,000 tons and 32,000,000 tons respectively. Portions of the Iron Monarch deposit are highly manganiferous, and, owing to the demands of the furnaces for ore yielding less than 1 per cent. of manganese in the pig-iron, this manganese is a disability which has to be met by blending with the non-manganiferous portions of the ore bodies. For this reason the ores of Middleback will be of especial value to the Broken Hill Proprietary Company, which controls both these great deposits.

THE BRITISH ASSOCIATION.—Invitations to the ninetieth meeting of the British Association, to be held in Hull from Wednesday, September 6, to Wednesday, September 13, have now been issued. Sir Charles S. Sherrington, President of the Royal Society, a physiologist, will be the president, and he will deal in his address with "Some Aspects of Animal Mechanism." Professor H. Hudson Beare will preside in Section G, Engineering; he will, in his presidential address, discuss the "Railway Problems of Australia." One of the subjects to be discussed by Section G is "Reformed Mathematical Teaching." There is little further information about the programme available at present. Members intending to present papers should communicate with the Recorders of the Sections; these are: Section A, Mathematics and Physics, Professor A. O. Rankine, Imperial College of Science and Technology, S.W. 7; Section B, Chemistry, Professor C. H. Desch, the University, Sheffield; Section G, Engineering, Professor G. W. O. Howe, Elmswood, Malden, Surrey. For general information readers should apply to the Secretary, the British Association, Burlington House, Piccadilly, W., and as regards accommodation in Hull, to the Hon. Local Secretaries, the British Association, the Guildhall, Hull; early application is advisable, especially in the latter case.

A NEW FORM OF HYDRAULIC RAM.

On Monday, the 12th inst., there was a demonstration at Carshalton of a new form of hydraulic ram, devised by Mr. T. G. Allen, of Messrs. Allen-Liversidge, Limited, 106, Victoria-street, Westminster. As in the case of the ordinary hydraulic ram, the object of the apparatus is, by making use of a low fall, to raise water to a height considerably greater than the available head. The principle involved will be readily understood on reference to Fig. 1. Here B represents an open tank placed at the top of a weir and communicating with the water above the weir. At half the height of the available fall there is fixed a closed tank A, which communicates with B through the pipe G, and with the tail race by the siphon pipe H, the upper bend of which is at nearly the same level as that of the water above the weir. On the pipe G there is a valve W controlled by the balanced lever V. To start the



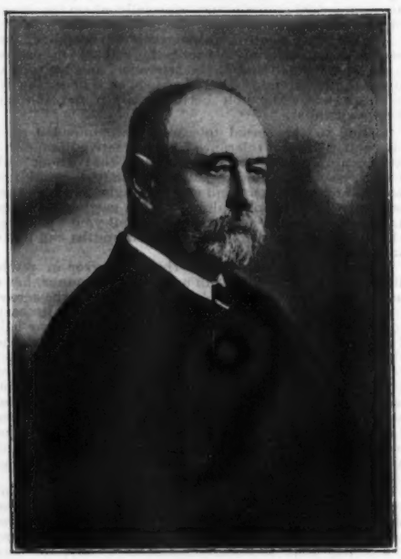
apparatus, this valve W is opened and water accordingly flows into A, forcing the air there up the pipe F. Hence, any water which may be in the closed tanks C will be forced up into the open tanks D and E from which it cannot return. When the chamber A is at last completely full, the water in the siphon pipe H rises above the bend and primes the siphon. The consequent discharge impinging on the impulse plate carried by the lever V, moves it so as to close the valve W. The siphon continuing to run, a vacuum is created in A and in the pipe F, and the closed chambers C. Water is accordingly sucked up into these chambers through the pipes T. When the chamber A is empty, the discharge from the siphon ceases, and the balance weight pulls over the lever V and opens the valve W, thus starting a fresh cycle. It will be seen that the apparatus, to which the makers have given the name "hydrautomat," differs from the ordinary hydraulic ram, in that its one valve is not subject to shock, and no high pressures are anywhere generated. On the other hand, as the total lift has to be divided up into steps, each rather less than half the height of the total fall, much more piping is required than with the ordinary type of ram, and moreover at each stage an open and a closed tank has to be provided. It will be evident from a consideration of the action of the apparatus, that, if required, a fall of dirty water can be utilised to lift clean water from another source.

Rolled Steel Wheels for Heavy Motor Vehicles.—The Consolidated Steel Corporation, of 139, Fenchurch-street, London, E.C. 3, which represents in this country the interests of a large group of American iron and steel works, is now putting on the market a rolled steel wheel for heavy motor vehicles which has been developed by the Bethlehem Steel Company. The wheel is constructed from a wide-flanged steel joist. The first operation is to punch three rows of elliptical holes along the web of the joist. A second punching operation separates the beam into two parts along the centre line of holes, and at the same time divides the webs between the other holes so that the webs are reduced to independent projections from the flanges. These projecting pieces are next dished and staggered so that they take the form of spokes. Each half-beam is then curled up into a circular form with the flange outwards and the ends welded together. The internal ends of the spokes are welded on to a central boss. The finished wheels are claimed to be as light, or lighter, than wooden wheels of equal size, and lighter than any other type of metal wheel.

THE LATE MR. JAMES BAIN OF THE CUNARD LINE.

At the ripe age of 81 years, and with a splendid record of work, there has passed away, to the regret of many friends, Mr. James Bain, who, for more than half a century, exercised a great influence on the development of marine engineering, having been for about thirty years superintending engineer of the premier Atlantic line—the Cunard Company. All recognised in his character that sound practical commonsense which is attributed generally to the Scotch race, and to this endowment of nature he added almost a unique training in engineering because, following upon his service, first, as an apprentice and constructive engineer and, second, as a sea-going engineer, he became supervisor of the design, building and operating of marine machinery. He was responsible for many new applications and yet he was conservative by nature. This only increased the confidence with which his opinions were received, because he had first to be satisfied as to the practicability and efficiency of any innovation before he would accept it. This, combined with his readiness to consider any such innovation, marked him out as a sound pioneer in engineering. He had pre-eminently the further quality essential to success that he always knew what he wanted and made sure that he got it.

In view of his career it was a coincidence that he was born, in 1841, in Lancefield House, which stood on the



site which, some years later, was occupied by the engineering offices of Robert Napier's firm. His father was a cabinet maker, who was responsible for the cabin fittings of early ships, and entered Napier's service when the latter began the building of ships. It was therefore a natural sequence that the subject of our memoir should have become apprenticed, in 1856, as an engineer in Napier's works. When one remembers that he was responsible for the introduction of turbines to high-speed liners of 25 knots to 26 knots speed, it will convey some idea of the influence he exerted to state that at the completion of his apprenticeship the Atlantic ships, which depended on paddle wheels and sails, rarely exceeded 14 knots speed and had a horse-power of not more than 5,000. Mr. Bain continued as constructive engineer for some time after his apprenticeship, but wisely decided to seek the experience which the management of machinery at sea conferred. Thus, in 1863, he joined the staff of the Cunard Company. With them he continued for some years, and, later, was chief engineer of the White Star steamers. He was thus at sea in the period that saw the transition from paddle wheels to screw propellers, but it cannot be said that there was any great advance either in the size or power of merchant steamers, as the later ships in which he served had not increased to more than 400 ft. in length, 4,000 tons gross, and 14½ knots speed.

In 1875 Mr. Bain became an engineering surveyor of Lloyd's, and, after serving a short time at the London office, was appointed first to Sunderland and afterwards to the Hartlepool district. For ten years he continued with Lloyd's, and then rejoined the Cunard Company in time to make the first voyage in the Etruria, which, with her sister ship the Umbria, marked a distinct advance in every respect in the design of Atlantic liners and their machinery. From this time onward, until his retirement a few years ago, Mr. Bain exercised a progressive yet safe policy in connection with marine machinery. Indeed, it may almost be said that the engines built under his supervision for the Cunard Company were regarded successively as the best and most reliable types of their respective years. His aim was reliability in the first instance, associated, as it necessarily had to be on the Atlantic service, with high speed and economy. He was, of course, early in his recognition of the advantages of compounding and of the twin-screw system. He was averse from innovation for novelty's sake, having no ambition to appear "in the limelight." One of his first bold steps was in connection with the Campania and Lucania, of 1893, which marked a 50 per cent. advance in displacement and nearly 100 per cent. advance in power, as compared with the Etruria, the power increasing to 27,650 i.h.p., and the speed to 21¾ knots. For many years these vessels maintained a high place for their reliability, and Mr. Bain's reputation continued to grow. Thus, when the Admiralty appointed a committee to consider the whole question of boilers for naval ships, under the presidency of Admiral Domville, Mr. Bain was appointed a member, and his experience and judgment were valuable; moreover, his work in connection with practical tests of the efficiency of the boilers and the system of draught fitted in the Cunard liner Saxonia materially contributed to the value of the report prepared by the committee.

Mr. Bain naturally watched with careful, although characteristic conservative interest, the development of the steam turbine and its operation in Clyde and Channel steamers. Ultimately the Cunard Company appointed a Committee, under his chairmanship, to investigate the suitability of the system for the propulsion of Atlantic liners. Almost simultaneously an Admiralty Committee was considering the design of battleships. It is often assumed that the latter committee, in deciding upon the adoption of turbines for the Dreadnought gave the first great impetus to the system, but the Cunard Committee were so satisfied with the results obtained in smaller ships that they decided to fit turbines driving treble screws to the Carmania, which was completed in 1905. They also decided that the two great ships built under Government subsidy for establishing British supremacy on the Atlantic, namely, the Lusitania and the Mauretania should also be fitted with turbine machinery, driving four screws. These vessels may, in a measure, be regarded as the culminating success of Mr. Bain's career as an engineer, and it is interesting to note that from the time of his first entry as an engineer into the Cunard Company the power of machinery had increased from 4,900 to 72,500, the gross tonnage of the ship from 3,870 to 33,700, and the speed of the ship from 14 knots to 26 knots; while, as a mark of the economy, it may be said that the fuel consumption was reduced from something like 4 lb. or 5 lb. per horse-power to somewhat under 1½ lb. per horse-power hour. At the same time there had been great advance in the efficiency of the machinery, including the auxiliaries, so that in his practical work Mr. Bain achieved marked success.

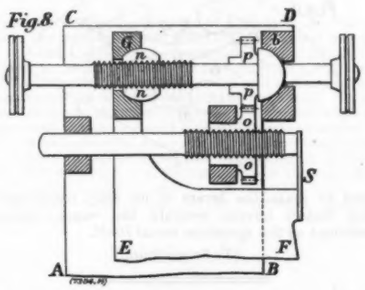
Mr. Bain, as we have already hinted, confined all his energy to the work in hand and rarely took any part in public life. He became a member of the Institution of Naval Architects in 1886, and was elected a member of the council in 1907 and a vice-president in 1917. He was elected a member of the Institution of Civil Engineers in 1905, and was also a member of several of the provincial engineering organisations. He took little or no part in the proceedings of any of these institutions. He was, however, a regular attendant at the meetings, and in those social functions connected with the gatherings was always welcomed, because of his rich fund of engineering knowledge, his quiet bonhomie and his charm as a raconteur. It is some years since he retired from the superintendentship of the Cunard Line, and the announcement of his death, at Hexham, Northumberland, on the 8th inst., has been received with deep regret by a wide circle of friends.

Machinery and Millwork in India.—The Department for Overseas Trade reports that during the year 1921–22 there was a prodigious import of machinery and mill work into India, nearly 83 per cent. of which came from the United Kingdom. Textile machinery for cotton and jute was imported to the value of 11·96 crores of rupees, whilst the imports of electrical machinery was valued at 3·90 crores. Our most serious competitor in the machinery trade is the United States, though a large fraction of the rice mill machinery and sugar-making plant came from Germany. From America 802 motor cars were imported, which were valued at 37·5 lakhs, whilst 790 cars valued at 83·7 lakhs were obtained from the United Kingdom. There were also heavy imports of railway plant and rolling stock, almost the whole of which was obtained from Great Britain, as out of a total value of nearly 19 crores, the imports from the United Kingdom was valued at 184 crores.

THE MECHANICAL DESIGN OF SCIENTIFIC INSTRUMENTS.*

(*Continued from page* 730.)

The Screw Pair.—Though we could, by suitable application of 5 deg. of constraint simulate the turning and sliding pairs of mechanism in a surprisingly simple manner, Professor Pollard stated in the second lecture, we could not do this with the screw pair, the third and most complicated of the three unique lower pairs of mechanism. The screw pair was a degree of constraint of the most general character and could not be produced by constraining one point of the body to a curved surface. For the screw pair prevented one line of the body from any longitudinal motion except that accompanied by rotation round this line in fixed proportion to the longitudinal translation, leaving every other motion free. Those other free motions were two rotations about axes perpendicular to that line, and two translations perpendicular to the same line, thus 4 d.f., which, together with the degree of freedom to screw and to 1 deg. of constraint, made up the six elements. Possibly the most remarkable of all the ingenious mechanical inventions of man the screw was the most troublesome to manufacture. The Whitworth thread, *e.g.*, had seven elements: Full or overall diameter; core diameter at the root of the thread; effective diameter; pitch; angle; radius at crest; radius at root. An immense amount of work had been done during the war on the production of the screw pair. Ingenious methods and delicate checks had



been devised, but it was impossible to manufacture the screw pair with the same degree of precision as the turning and sliding pairs. Specifications for manufacture were sometimes exacting to an impossible degree; Professor Pollard exemplified this by referring to the double-threaded clinometer screw which the authorities demanded during the war, and which the Cambridge and Paul Instrument Company improved (compare Figs. 11 and 12 of Mr. Whipple's address, ENGINEERING, of May 27, 1921, page 659.

Backlash.—As there must be in general allowance between a screw and its nut for the purpose of its manufacture, there must be backlash. The backlash was troublesome, however, and had to be exactly determinate or to be eliminated when the screw was one of the metric elements. The latter could be effected by keeping screw and nut in contact with the helical surface of the thread by pressure applied in the line of axis, and this was most simply and effectively done by Whitworth in his Millionth Measuring Machine, the forerunner of all modern measuring machines. The nut was first made and cut into two portions; the tangent screw was also made in two halves and made to press both sides of the screw-wheel teeth, just as the nut was adjusted to press both sides of the square thread. In a modification of this design, Kelvin's micrometer screw for electrometers, the secondary nut was prevented from turning and pressed away from the primary nut by an intervening spring. The two nuts being on the same screw, the distance between them remained constant during the rotation of the screw spindle, and the axial pressure distributed over the threads of spindle and nut did not vary.

In another device invented by Grubb, in 1886, for the Declination Slow Motion of Telescopes (Fig. 8), A B C D was a portion of the arms attached to the telescope or cradle, and E F G was the clamp arm. The screw had a bearing *b* with spherical seating on the telescope arms, and its nut *n* bore in the bearing G of the clamp arm, to which a short stiff spring S was attached bearing, not directly against the other arm, but against the end of a second screw (of the same pitch as the main screw), the nut of which was a pinion *o o* engaging with a similar pinion *p p* on the main screw. This second screw advanced as much in one direction as the frame A B C D was carried in the other, when the milled head was turned, and consequently the point of the screw did not sensibly vary its position with respect to the clamp arm E F G. In this way a short stiff spring brought a constant pressure to bear between the main screw and its nut.

Microscope Adjustments.—Elimination of backlash by splitting the nut so that it could suitably be clamped upon the screw was adopted in the fine adjustment of the large Zeiss photomicrographic microscope stand which some people had pronounced to be so perfect in its action. In this arrangement the split nut, shown in section in Fig. 9, surrounding the vertical micrometer screw, was conical, and was forced into a conical hole attached to the body tube by means of a secondary nut. In this way the split nut could be made to close in upon the micrometer screw. The method had to be used with caution, however; for if contact took place between the roots and crests to the exclusion of contact between the helical thread surfaces, rapid wear and erratic motion would develop.

In the Fabry-Perot interferometer of Messrs. Adam Hilger, the nut of the screw spindle was split and clamped by screws, the thread was specially designed, crests and roots cleared one another, and when the nut was clamped, the pressure was taken up by the helical surfaces of the threads only. With the Whitworth form of thread the clearance of roots and crests gave too small a bearing on the helical surfaces; the thread had therefore been redesigned for an angle of 47 deg., instead of the standard Whitworth angle of 55 deg.

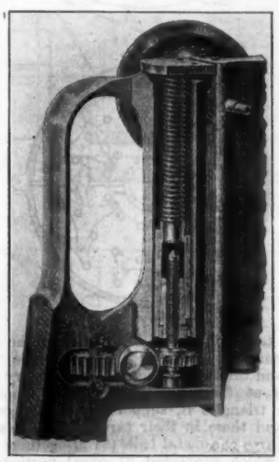
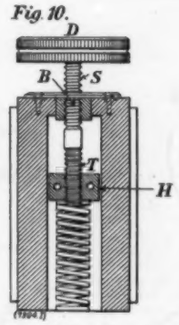
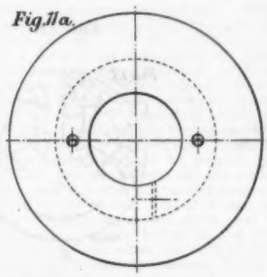


FIG. 9.

The fine adjustments of microscopes were in most instruments either screw or lever devices, designed to magnify the movement of the optical system at the milled head. The function of the fine adjustment in research instruments should chiefly be metric, and the fine adjustment should not serve for mere focussing. The velocity ratio of the mechanism should hence be constant, *i.e.*, unit turn of the milled head should always move the optical system through the same distance. That was hardly possible with lever systems which were, moreover, liable to wear and to develop variable contacts. Campbell's differential screw was peculiarly adaptable to fine microscope adjustments (Fig. 10). Two screws of different pitches were cut on the same spindle; the first screw S engaged with a nut fixed to the limb of the instrument B, the second screw T engaged with the nut H fixed to the tube carrying the optical system. A single rotation of the milled head D advanced the screw and carried the tube with it through a distance equal to the pitch, but the second screw caused its nut and hence the tube to advance in the opposite direction through a distance equal to its own pitch. When, therefore, the milled head advanced through a distance equal to the pitch of the first screw, the tube moved through a distance equal to the difference between the two pitches. With screws of 30 and 31 threads to the inch, the optical system then was advanced through $\frac{1}{30}\frac{1}{1}$ in. by one turn of the milled head, which itself moved axially through $\frac{1}{30}$ in. A delicate minute movement was thus given by two screws of coarse pitch and robust construction, and when a vertical scale was placed against the edge of the milled head, $\frac{1}{30}$ in. on the scale represented a movement of $\frac{1}{30}\frac{1}{1}$ in. of the movable system. With a spindle provided with 20 and 25 threads respectively, the tube movement corresponding to unit turn of the milled head would be $\frac{1}{20}\frac{1}{5}$ in., and any desired velocity ratio could be





obtained. Professor Pollard was at a loss to understand why this almost perfect adjustment for microscopes had gone out of fashion. Professor Pollard also exhibited and described in detail the ingenious microscope with geometric slides of the late Dr. Keith Lucas (Journal Microscopical Society, 1904.)

The success of measuring instruments depended frequently upon the way in which the nut or screw spindle was connected to the moving piece and the way in which endlong motion of the spindle was prevented. An excellent design obviating possible strain between screw and nut was shown in the feed-screw mechanism of the rocking microtome of the Cambridge and Paul Instrument Company (see Fig. 10, page 661, of ENGINEERING, May 27, 1921. A simple device, due to Sir Horace Darwin, to ensure contact between the end of the screw and the piece to be moved, was to close the kinematic chain by a constant-force closure in the form of a C-spring. If the end of the screw should not precisely be a surface of revolution about the axis of the screw spindle, however, the point of contact would describe a small closed curve on the bearing surface, and if this surface were not precisely square to the axis, a periodic error would develop and strains would be set up. These defects were met in the reading microscope of the Cambridge and Paul Instrument Company.

But such arrangements would not suffice for interferometer measurements within a fraction of a wavelength of light, $\frac{1}{1}\frac{1}{0}\frac{1}{0}\frac{1}{0}$ mm. In Messrs. Adam Hilger's beautiful construction of the Fabry-Perot interferometer the thrust of the spindle was taken up by a quartz plate bearing against a small, highly-polished area on the end of the spindle which was produced before the spindle was unchucked from the lathe on which it was made, so that the area was dead square to the axis of revolution. When the point of contact of the spindle and quartz plate was observed through the latter, interference bands were seen. These bands would shift during a turn of the spindle if the plate were not dead square, and the plate could then be adjusted until no more shifting was observed.

Backlash in Toothed Gearing.—Backlash was very troublesome in gearings in which teeth engaged with one another by sliding or rolling contact. How this could be overcome for bevel gear was illustrated by the excellent design for mass production of the refractometer of Messrs. Bellingham and Stanley. Mr. William Taylor prevented backlash between the index plate of the Taylor, Taylor and Hobson Dividing Head and the face-plate in the way shown in Fig. 11. The index plate was centred by fitting closely and squarely up to a shoulder on the plain cylindrical extension or hub of the dividing-head face-plate, to which it was secured by two taper pins projecting from the face of the split collar. These pins engaged in holes made in a diameter of the index plate, but the pins on the collar were so placed as to engage holes both on one side of the diameter, towards the slit in the collar. The index plate was pushed on to the hub and pressed up to the shoulder by the split collar, the pins forcing the plate into contact with the hub and eliminating backlash. Tightening the collar then further tended to jam the plate. This was essentially a manufacturing proposition; for not only were the alignment of holes and pins and their misfit avoided, which would be very troublesome in manufacture, but the backlash attendant upon such alignment was entirely got rid of. The design was compromised geometrical.

Before leaving the screw pair Professor Pollard mentioned the troublesome crossing of screw threads when engaging two screw members of large diameter and small pitch. When one member was provided with a cylindrical "pilot" by turning away a few threads to the root or core diameter, the co-axial relation was secured by the crests of one member engaging with the pilot of the other before the threads engaged. For the

* Abstract of three Cantor Lectures, delivered in February and March last before the Royal Society of Arts by Professor Alan F. C. Pollard, A.M.I.E.E., F.Inst.P., Department of Optical Engineering, Imperial College of Science and Technology, South Kensington.

same purpose Mr. W. Taylor milled away the tapering portion at the commencement of the thread on both members; this "abrupt" thread was especially useful for lense-mountings. In cases where several lens mounts were assembled in a tube and had frequently to be changed for varying the optical system or for cleaning, Mr. Taylor mounted the lens in a short cylindrical cell, the outside diameter of which was slightly less than the outside diameter of the tube it had to fit. A little more than half this circumference was milled away to a radius equal to that of the inside of the tube, and the tube itself had a slot milled across it extending nearly to the diametrical plane of the tube and of a width equal to the height of the mount. The mount would then snap into the tube. Fig. 12 illustrates this cell mount for the optical system of the "Talynden."

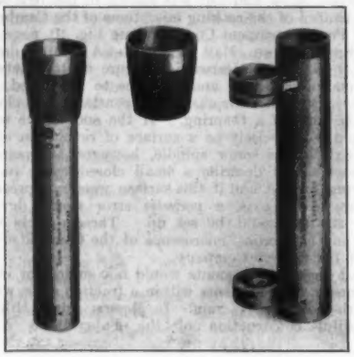
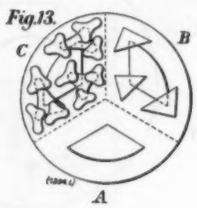
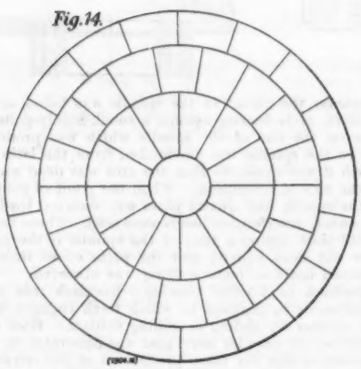


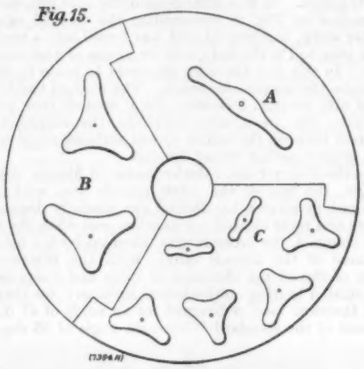
FIG. 12.

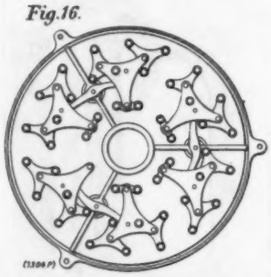




Returning to the geometrical slide Professor Pollard pointed out again that a body having contact at five points on five surfaces was constrained to move with one degree of freedom and enabled to take up a position of repose without being subjected to unnecessary strain in any part. If, therefore, we merely required the body not to have rotation about the two horizontal axes and to be constrained in one of its translations only, we might remove two more surfaces and allow the body to rest on three. Thus a body would rest by three points on an uneven fixed surface without unnecessary strain. A heavy body would bend, however, and that was the necessary and unavoidable strain. That bending would increase with the distance between the supports, and the question arose whether it was possible to extend the principle of a three-point support so as to reduce the flexure. It was evident that, provided we did not fix any of the subsidiary points of support and limited the fixed surfaces to three, the body would remain free to take up its position of repose. The body would thus remain in a state of repose if supported at nine points by means of three frame works, each with three bearings, and each frame working at one point on each of three fixed bearings. The process could be pushed to any extent.

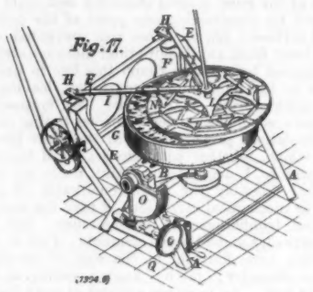
Supports for Telescope Specula.—Professor Pollard illustrated this first by describing the way in which Lord Rosse, in 1861, supported the 6-ft. speculum of his giant telescope, which weighed over 3 tons. The cast-iron carriage carried three ball and socket joints, directly under the centres of gravity of three equal sectors A into which the speculum (Fig. 13), might be supposed to be divided. The centre of the ball was in the centre of gravity of the triangle both as to plane and thickness. These three primary triangles A carried at their angles, by ball supports, nine secondary triangles B, supported at their centres of gravity, and these in their turn 27 triangles C each carrying three gun-metal balls (81 altogether) of 1¼ in. diameter which supported 27 equal portions of the speculum. Between the balls and the speculum 27 thin brass plates were interposed and attached to the speculum by pitched cloth to make a smooth path for the balls to roll upon without grinding the back of the speculum. The iron polishing tool weighing over 1 ton was suspended by 36 points in similar manner.

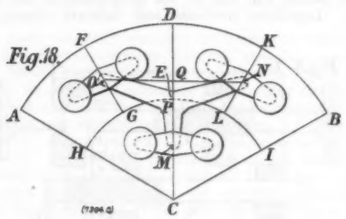




This vertical support of the speculum was in principle the same as that applied by Howard Grubb to a 15-in. speculum constructed by him for the Armagh Observatory. In Grubb's 4-ft. speculum of the Great Melbourne Telescope the arrangement was again similar, but the levers were packed into a smaller space vertically. The speculum was supposed to be divided into 48 portions of equal weight (Fig. 14). These portions were supported by the 48 points of 12 triangular levers and 6 straight levers shown at C (Fig. 15), the centres of these 18 tertiary levers were supported by six triangular secondary levers, two of which are shown at B. The centres of the secondary levers were supported by the three primary levers A, and the centres of the latter finally were supported on three fixed surfaces of the frame. Fig. 16 shows the actual arrangement of the lever system, and these arrangements were further explained by Fig. 17 (polishing tool with its lever system).

In Lascell's method of supporting large specula (Fig. 18) the sector of 120 deg. was divided up into six equal areas, and thus the whole speculum into 18 equal portions. The circles represent discs of brass bearing against the back, the centres of which coincided with the centre of mass of the elementary areas of the speculum. Pairs were connected by short levers, at each end of which was a hole, loosely-fitting pins projecting from the discs; the under surfaces of the discs were small segments of spheres. The centres of these levers were again supported by the ends of a triangular lever M N O in the same manner as the discs were supported by the first three levers. Finally the point P of this lever was supported on a screw or stud fixed in the end plate of the telescope tube; this point P being the centroid of the loads at M N O, P M was equal to 2 P Q. Thus the mirror was ultimately supported on three points. Lascell found that the mirror was distorted with change of temperature and rightly assigned this defect to differential expansion between the iron of the levers and the speculum metal and to the fixation of the various points of support. By making the surfaces of contact of the discs as smooth as possible he removed this defect to some extent; to remove it entirely he proposed to make the levers of an alloy (described by Lord Rosse) having sensibly the same expansion coefficient as the speculum metal itself.





(To be continued.)

LOSSES IN NOZZLES OF RECTANGULAR SECTION.*

By D. S. ANDERSON, B.Sc.

WITHIN recent years an immense amount of experimental work has been carried out on the flow of steam through nozzles. The bulk of this work has been carried out on round nozzles and little or no attention paid to the rectangular shape. No doubt the choice of the round type is due to its inherent simplicity of form and the desire to eliminate, so far as possible, the effect of individual peculiarities when searching for general laws. Nevertheless, it is not a form which is found to any great extent in practice, except perhaps in some small power units of the De Laval type, and the laws developed for round nozzles may not apply accurately to the unsymmetrical rectangular shape. As a matter of fact, although the problem of the round nozzle has been attacked many times by eminent investigators very little has been got out of it; discharge coefficients, reaction and impact values have been obtained more or less accurately, but these, while giving overall effects, give absolutely no indication as to the nature of the loss or its mode of occurrence. Such overall information is quite useful when applied to nozzles of a type exactly similar to that from which the information was obtained, but is utterly useless for application to radically different types. To be able to make such an application with a fair degree of accuracy the nature and mode of occurrence of the losses would have to be known. Once these were known in a fundamental way application with necessary modifications could then be made to other types. And for the investigation of the behaviour of practical nozzles with all their complexities of shape, form and surface, some such preliminary fundamental knowledge seems to be essential. The meagreness of the data hitherto obtained from even the simplest nozzles clearly shows the futility of a direct attack on complicated practical shapes.

Quite recently the problem of the simple round nozzle was again attacked, and this time successfully solved by the united efforts of Dr. A. L. Mellanby and Mr. W. Kerr, of the Royal Technical College. These able investigators have demonstrated† both the nature and mode of occurrence of the losses inherent in nozzles of convergent and convergent parallel form, and have thus added immensely to our knowledge of the true nature of the expansion of steam through a nozzle. The desire to get at the fundamentals of the phenomenon decided those investigators to use a simple round nozzle. The next step was obviously a transition from the simple round to the simple square nozzle, this being one step

* Paper read before the Greenock Society of Engineers and Shipbuilders, March 7, 1922.

† "On the Losses in Convergent Nozzles." North-East Coast Institution of Engineers and Shipbuilders, February, 1921.

nearer the practical form. The peculiarities of the round form being so clearly demonstrated provided a starting point for the attack on the more complicated square or rectangular form. Accordingly a series of experiments was carried out on nozzles of rectangular shape, under the supervision of Dr. Mellanby, the results of which will be given in this paper.

For the sake of clarity a very brief *résumé* of the analytical methods employed by those authors will be given here, though those desiring a more detailed account should refer to the paper read before the British Association in 1920.*

The only assumption made in the theory is that the expansion of the fluid is confined to one field for which the adiabatic index n is fixed and unalterable. Under this condition the standard expression connecting the flow quantity, cross-sectional area and initial conditions is

$$\frac{G}{A} = \frac{1}{144}\sqrt{\frac{288\,g.n}{n-1}\cdot\frac{P_1}{V_1}\cdot\frac{1-r^{\frac{n-1}{n}}}{r-\frac{2}{n}}} \quad . \quad . \quad (1)$$

where G = flow quantity, lb./sec.
A = cross-sectional area, sq. in.
P_1 = initial pressure, lb./sq. in.
V_1 = initial specific volume, cub. ft./lb.
r = pressure ratio of operation P/P_1 at the section A.

For superheated steam $n = 1{\cdot}3$ and the above expression may be reduced to

$$0{\cdot}718\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}}\frac{G}{A} = \frac{r\left(1-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}}{r^{\frac{n-1}{n}}} \quad . \quad . \quad . \quad (2)$$

For any fixed pressure ratio of operation, *i.e.*, for any fixed r, the right-hand side of (2) is constant and therefore the left-hand side will be constant. Any ordinary expansion is, however, more or less imperfect. This will cause a reduction in the value of G and a corresponding reduction will be entailed in the right-hand side. Experiment has shown that, while the value of the left-hand side is less than the theoretical, it is still constant within the limits of experimental error for any given pressure ratio. The defect in value from the theoretical is therefore reasonably constant, and we may express the right-hand side in some modified way to indicate this.

The most suitable form of the expression has been shown to be

$$\frac{r\left(1-k-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}}{k+r^{\frac{n-1}{n}}}$$

where k is always positive and represents a loss factor of some kind.

The form of the complete expression as applicable to an actual expansion is therefore

$$0{\cdot}718\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}}\frac{G}{A} = \frac{r\left(1-k-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}}{k+r^{\frac{n-1}{n}}} \quad . \quad . \quad (3)$$

The quantities involved in the left-hand form of the expression all lend themselves to comparatively simple measurement or computation. P_1 can be read directly, V_1 can be computed knowing P_1 and the temperature; G can be obtained by condensing and weighing the quantity of steam passed in a given time, and A can be obtained by measurement and subsequently corrected for the expansion with rise of temperature. Thus the value of the left-hand side of (3) can be easily determined. This is also the value of the right-hand side, which contains two unknowns, r and k. r is the pressure ratio and can be determined by passing a search tube along the axis of the jet. The determination of r permits the calculation of k, the loss factor, and the performance of the nozzle can then be fully determined.

The most suitable type of experiment will therefore be one which gives G, the quantity passed, along with a curve showing the pressure fall along the nozzle. Such a curve can be easily transformed into one of pressure ratio, which is the value desired. As already stated, the assumption is made that the expansion of the steam is confined to one field for which the adiabatic index n is fixed and definite. To ensure the fulfilment of this condition the steam was superheated to such a temperature that in the subsequent expansion the saturation line was never crossed. This obviated the difficulty of having the expansion take place in the wet field where the existence of a certain though indefinite amount of supersaturation would only complicate the results.

Briefly, then, the experiments were all carried out using steam sufficiently superheated to ensure that the whole expansion took place in the superheat field. A search tube was passed step by step down the axis of the jet, corresponding readings of position and pressure being taken. The supply pressure and temperature were carefully noted, and also the flow quantity G passed in a given time. This provided all the necessary data to determine the nozzle performance. A fixed initial pressure of 60 lb. G was maintained and the pressure ratio of operation altered by varying the back pressure from atmospheric to 50 lb. G. The superheat was of the order of 160 deg. F. This kept the end point of even the full expansion within the superheat field.

* "Steam Action in Simple Nozzle Forms." British Association, Section G, August, 1920; ENGINEERING, September 3, 1920.

The expression

$$0{\cdot}718\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}}\frac{G}{A} = \frac{r\left(1-k-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}}{k+r^{\frac{n-1}{n}}}$$

is called the jet function and denoted by the letter F. From the experimental readings just detailed F can be determined from the left-hand form of the expression. This form is capable of two interpretations. Considering the nozzle operating under fixed initial and final conditions, V_1, P_1 and G are fixed, and the only variable is A. The variation in the value of F is then its variation along the nozzle length. For a convergent parallel nozzle A is constant in the parallel portion, and hence F will be constant. The corresponding interpretation of the right-hand side is the variation of r along the nozzle length with the corresponding growth of k. The other point of view is to fix the attention on any particular section of the nozzle say, the outlet section, and consider different pressure ratios of operation by raising the back pressure. V_1, P_1 and A are constant, and G is now the variable, giving the different flow quantities with different pressure

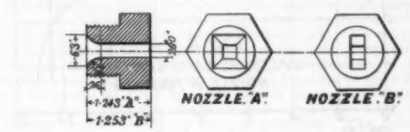
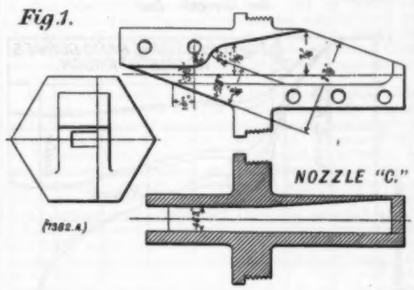


Fig. 1.



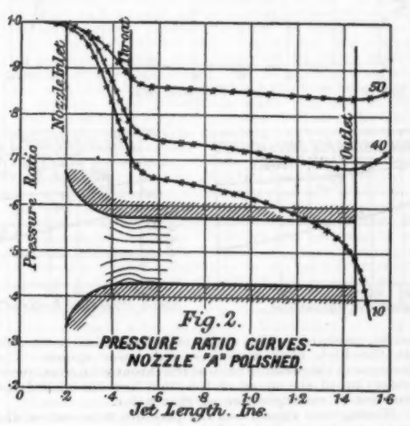


Fig. 2. PRESSURE RATIO CURVES. NOZZLE "A" POLISHED.

ratios of operation. In the right-hand side r is the pressure ratio of operation, and K gives the total value of the loss occurring in the nozzle.

Three types of nozzles were used as shown in Fig. 1. A is a square convergent parallel nozzle with the convergence at the entrance on all four sides. B is similar in form except that the convergence is made on two sides only; the remaining two are flat and parallel. C is a convergent parallel nozzle of practical form and is, in fact, an exact replica of a nozzle at present fitted to a 250-kw. turbine at the Royal Technical College. All three nozzles were first tested in a highly polished condition. Afterwards nozzles A and B were roughened, by scoring the surfaces with a file, and the tests repeated.

Fig. 2 shows the pressure ratio curves obtained from nozzle A with polished surface. The pressure ratio at any point is, of course, the pressure at the point divided by the supply pressure. The position of the curves relative to the nozzle is shown by having the nozzle form sketched in, in its proper position. The forms of the curves are quite definite and well defined, as shown by the good agreement of the large number of experimental points used to determine them. An extremely rapid portion of the expansion occurs in the convergence, while in the tail or parallel portion the expansion is much more gradual.

In view of the very ample entrance curve one would expect that the jet would conform to the nozzle boundary all the way along. An examination of the pressure ratio curves will show that this is not the case. If the jet conformed to the nozzle boundary all the way along, the pressure ratio curve would turn from the steep to the gradual portion of the curve just where the entrance curve joins the parallel portion. This is what takes place in round nozzles even when the entrance curve is much sharper than the one under consideration. In this case, however, we see that the end of the entrance curve lies on the steep portion of the expansion curve, and, consequently, rapid expansion is continuing to take place in the parallel portion. The explanation of this is that the jet has left the nozzle boundary and is continuing free, rapid expansion even after the convergence is finished. The conditions at the throat (using this term only in the sense of the end of the convergence) will be approximately as shown by the boundary lines sketched in at the foot of the figure. Sooner or later, of course the jet comes back to the wall and the expansion proceeds smoothly to the outlet.

The inability of the square nozzle to make the jet conform to the nozzle boundary is not an individual characteristic of this particular nozzle, but is a general characteristic of all the square nozzles yet tested. The effect is probably due to the unsymmetrical nature of the convergence. Unlike the round nozzle the convergence is not the same in all radial directions around the axis. This lack of symmetry must exercise a disturbing influence on the expansion, though why it should be shown by the jet leaving the boundary wall is not quite clear.

A feature common to the partial expansions with high back pressure is the tendency of the nozzle to over-expand as indicated by the recompressions in the free space beyond the nozzle outlet.

Dealing now with the full range curve alone we see that the lowest pressure ratio at the outlet is 0·490, as compared with the theoretical 0·546; further, the pressure ratio at the end of the convergence is comparatively high, so that there is a fair drop of pressure along the parallel portion. Accepting the well-established fact that the limiting velocity to which a nozzle of this type can expand is the velocity of sound corresponding to the state of the medium, the reason for the low value of the outlet pressure ratio can be readily deduced. With perfect expansion and no losses the energy liberated by an expansion to a pressure ratio of 0·546 is sufficient to generate in the fluid a speed equal to the speed of sound in the fluid at the critical pressure conditions. If, however, the expansion is imperfect and losses take place, some of the energy is absorbed by these losses, and hence the fluid will not have attained the speed of sound, at a pressure ratio of 0·546. The fluid not having reached its limiting speed, will continue to expand until it attains it; the extra expansion necessary will be greater, the greater the losses. This does not affect only the outlet pressure ratio; while it is lowered, the throat pressure is raised. One might expect at first that it should be unaltered, but a little consideration will show that it cannot remain unaffected. Severe losses in the tail mean a steeper velocity gradient since the outlet value of the velocity remains approximately constant, hence a smaller value of the velocity will be found at the beginning of the tail, *i.e.*, a higher pressure ratio will be found there.

Those three pressure ratio curves were obtained with the hole in the search tube pointing towards the middle of a flat side. To see if the same fall of pressure were taking place along different parts of the nozzle, the tests were repeated turning the nozzle so that the hole in the search tube pointed diagonally to opposite corners. The result is shown in Fig. 3, where both sets of curves are shown for comparison. The dotted curves are those already shown in Fig. 2; the full-line curves are those obtained from the second tests. The difference is quite startling and indicates very clearly the complex nature of the expansion taking place in a nozzle of this type. From the nature of the curves at the throat it would appear as though the jet left the nozzle boundary to a greater extent in the corners than at the flat sides. Such an effect might have been anticipated from the behaviour of a water jet issuing from a sharp-edged square orifice. The jet deforms by flattening in at the corners and bulging out at the middle of the sides, taking on a kind of cruciform shape. The change taking place in the nozzle under consideration is probably one of the same nature. Disparity exists between the curves throughout the whole length of the nozzle, approximate coincidence only being reached at the outlet.

In a nozzle expanding in this manner one would expect to find fairly high losses due to eddy currents in the main flow. With different pressure ratios across a plane cross-section in the parallel portion, the flow at all points cannot be at right angles to the cross-section. This entails a certain amount of loss and also renders inapplicable the jet function since A must be known to determine F. This effectively prevents any attempt to consider in detail the growth of loss along the nozzle, but, since the two pressure ratio curves are coincident at the outlet the flow here will be fairly steady and the jet function formula quite applicable. We will thus be able to deal only with overall effects, which is all that one could really expect with such a complex expansion. That the expansion in a nozzle of this type is complex and disturbed was evident from the behaviour of the pressure gauge registering the search tube pressure. Only at the beginning and end of the nozzle was there a reasonably steady reading; at all intermediate points the pointer was subject to frequent, in some places continuous, and violent oscillations showing clearly the unstable nature of the expansion. Further, while any one curve is quite well defined by the experimental points, different curves, equally well defined, could be obtained on different occasions. The difference between such curves though distinct was not great and indicated that there were several conditions of partial equilibrium probably all influenced by purely accidental occurrences.

After the completion of the tests the nozzle was roughened all over by scoring with a small file and the tests repeated. Fig. 4 shows the pressure ratio curves obtained with the new surface. To avoid unnecessary confusion in comparing the polished and roughened effects only one set of curves is used, the set obtained with

the search tube hole pointing to the side of the square. One notices again the inability of the nozzle boundary to make the jet conform to it. The turning point of the curves is not altered as regards its position along the nozzle. This would seem to indicate that the nozzle form and not the nozzle surface is the determining factor as to whether or not the jet will rigidly adhere to the walls. As a matter of fact, unless in the case of the perfectly symmetrical round nozzle, it seems that the jet always leaves the walls in this region even when provided with a more than ample entrance curve. The over-expansion noticed in the last case is also present here, but with the difference that, while in the previous case the recompressions took place in the free space beyond the nozzle outlet, in this case we have the re-compressions actually starting within the nozzle itself. Over-expansions are quite common in both round and square nozzles, but so far as the round nozzle is concerned the recompression always takes place in the free space beyond. In the majority of square nozzles yet tested the recompression tends to start within the nozzle. An explanation of this might be found in non-uniformity of velocity across a section; the more slowly-moving streams such as might be found in the corners would be more susceptible to the influence of back-pressure. The dotted curves are those of the polished nozzle. The difference between the two is very marked. The more severe losses due to roughening of the surface have caused the raising of the throat pressure ratio and the lowering of the outlet pressure ratio. This is most marked in the full range expansion where the velocities are highest, but is definitely present in the other two cases though in a lesser degree. The same characteristic

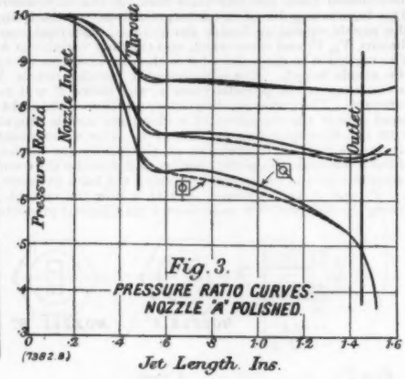


Fig. 3. PRESSURE RATIO CURVES. NOZZLE "A" POLISHED.

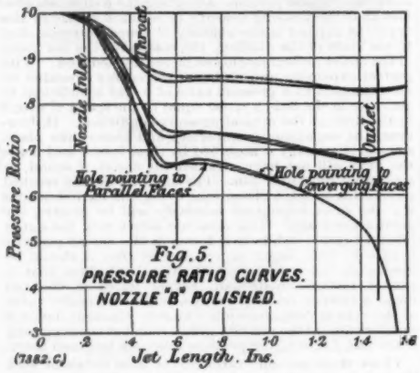


Fig. 5. PRESSURE RATIO CURVES. NOZZLE "B" POLISHED.

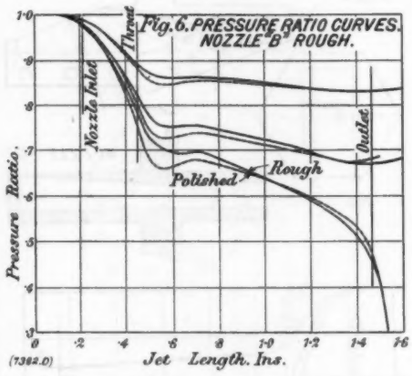


Fig. 6. PRESSURE RATIO CURVES. NOZZLE "B" ROUGH.

of instability of pressure reading was again in evidence; only the beginning and end of the nozzle gave good, steady readings.

The next nozzle dealt with was nozzle B. This nozzle is of the same dimensions as A; both were finished with the same broach. It, however, has convergence on two sides only; the other two are flat and parallel. This form approximates more closely than A to the actual forms found in practice. Two sets of tests were run on it, one with the surface highly polished and one after it had been roughened similarly to A. When in the polished condition two sets of pressure ratio curves were taken. In the first set the hole in the search tube pointed to the converging faces, while in the second set the hole pointed to the parallel faces. Both sets of curves are shown in Fig. 5. The full-line curves are those obtained with the hole pointing to the converging faces and the dotted those obtained with the hole pointing to the parallel faces. The difference between the two sets is very marked but irregular. Once again we have it clearly demonstrated that the nozzle boundary is incapable of compelling the jet to conform to it. The presence in the full line curves of the recompression at the bend of the curve shows that the jet must have left the boundary in this region. Judging by the amount of recompression the extent to which it has left the wall seems quite considerable. It is evidently dependent on the speed developed, since the effect is greater at the lower pressure ratios. With high back pressures the usual over-expansion and subsequent recompression is quite in evidence. The outlet pressure ratio is 0·475, as compared with the theoretical 0·546.

The curves taken with the hole pointing to the flat sides show an expansion of a different nature. At the very beginning it is more rapid. This is probably to be explained by the steam tending to expand in this region as for a sharp-edged or very little rounded entry. Here also the jet has left the wall for a very short period, as shown by the small but distinct depression in each curve. From here to the outlet the jet remains in contact with the walls all the way. One might anticipate this, as there is no disturbing factor which would tend to throw it off. The relationship between each pair of curves varies in the different tests, but agreement at the outlet is pretty fair, and in a complicated expansion of this type only overall conditions can be considered.

Fig. 6 shows the curves obtained from this nozzle after roughening the surface. The feature of the more severe losses is shown by the higher throat and lower outlet pressures. This effect, as before, is less noticeable at the high back pressures and lower speeds. The increase in the pressure ratio at the throat with consequent reduction of the speed of the fluid has diminished the amount of recompression at that point.

Having now drawn out the pressure ratio curves the next step is to calculate F from the expression

$$F = 0{\cdot}718 \left(\frac{V_1}{P_1'}\right)^{\frac{1}{n}} \frac{G}{A}$$

Knowing F and the pressure ratio at any section we are in a position to proceed to a computation of the total loss up to that section. Owing to the very complex nature of the expansion and the general uncertainty created by the double set of pressure ratio curves it would be impossible to get a detailed analysis of the growth of loss along the nozzle, but overall values can be readily obtained, and with probably fair accuracy. The uncertain factors in the progress along the nozzle are the area to flow and the pressure ratio. While a mean of the pressure ratio readings may be taken, the area is entirely indefinite, precluding any possibility of calculating F unless for the outlet section, where the flow seems to be reasonably steady. This is indicated by the approximate coincidence of the pressure ratio curves and the steady reading obtained on the gauge. It should be noted that the area to flow is not the nozzle area unless the jet is filling the nozzle and flowing parallel with the boundary. Assuming, then, and the assumption seems reasonable, that these conditions are fulfilled in the neighbourhood of the outlet section, we can calculate the value of F for this section. Knowing F by calculation and getting r from the curves already given, we can get k from the expression

$$F = \frac{r\left(1 - k - r^{\frac{n-1}{n}}\right)^{\frac{1}{n}}}{k + r^{\frac{n-1}{n}}}$$

To compute k directly from this expression would be a very laborious proceeding, so for simplicity a calculating chart is used. Fig. 7 shows this chart. It consists of a series of curves of

$$\frac{r\left(1 - k - r^{\frac{n-1}{n}}\right)^{\frac{1}{n}}}{k + r^{\frac{n-1}{n}}}$$

on a base of pressure ratio. To determine the value of k all that has to be done is to mark the value of F as determined from the other form of the expression against the appropriate value of r; k is then read directly from the chart. It has been already pointed out that the operation of the nozzle under fixed initial and final conditions will give the variation in the value of F the jet function or k the loss factor as we pass along the nozzle since G is constant and A variable. For the parallel portion A is constant, provided that the jet is filling the nozzle and that the stream lines are parallel to the boundary, and hence F will be constant over the same portion. The two conditions just enumerated are fulfilled in the case of round nozzles but not for square ones. No doubt the conditions are approximated to towards the end of the square parallel portion, but certainly not at the throat. The outlet condition being quite definite, we can mark it on the chart and draw a horizontal line of constant F value, the length of the line depending on the length of the parallel portion over which the conditions are estimated to hold. The loss factors k can be read from this line directly for different sections and plotted on a base of nozzle length. This enables a better approximation to the end value of k to be made than by merely using the outlet value as found from the chart.

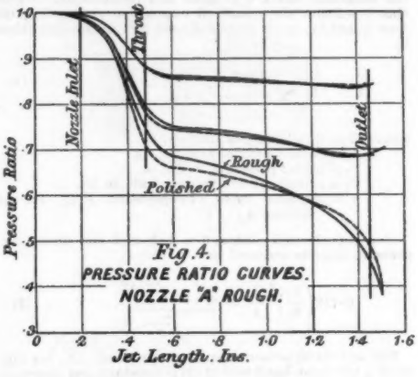


Fig. 4. PRESSURE RATIO CURVES. NOZZLE "A" ROUGH.

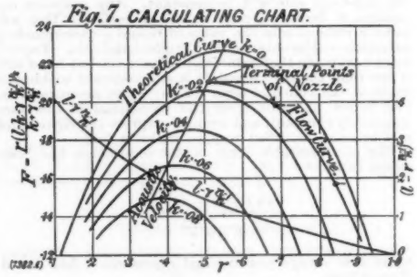


Fig. 7. CALCULATING CHART.

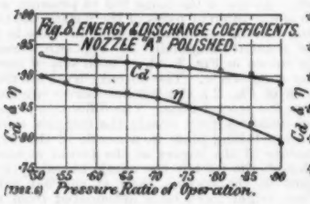


Fig. 8. ENERGY & DISCHARGE COEFFICIENTS. NOZZLE "A" POLISHED.

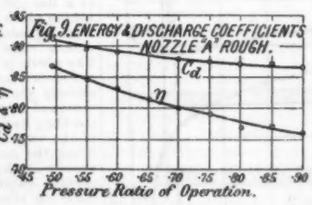


Fig. 9. ENERGY & DISCHARGE COEFFICIENTS. NOZZLE "A" ROUGH.

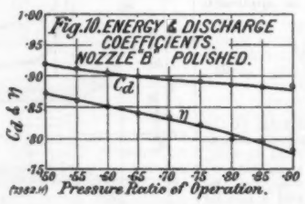


Fig. 10. ENERGY & DISCHARGE COEFFICIENTS. NOZZLE "B" POLISHED.

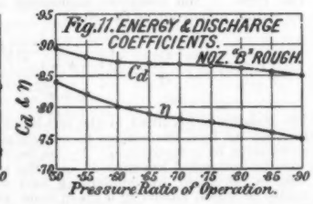


Fig. 11. ENERGY & DISCHARGE COEFFICIENTS. NOZ. "B" ROUGH.

Having determined the values of k for the different sections, we can plot them on a base of nozzle length and so get a curve showing the variation of k along the nozzle. This curve will be of the same general form as the pressure ratio curves, and will be subject to the same uncertainties. Its value, however, is that it enables us to see the effect of the different parts of the nozzle on the loss, and to see where the greatest losses occur. It is also of value in that it enables us to see the effect of the different nozzle forms on the loss.

On the chart there is marked a line acoustic velocity or velocity of sound in the medium at the critical conditions. This line marks the pressure ratios at which, with different losses, the limiting velocity of sound is reached, and should definitely mark the end point of the nozzle expansion. In reality in every case of full expansion the terminal condition lies to the left of this line; not much to the left, but having definitely crossed the line. The section which really lies just on the line is a section about 0·03 in. from the outlet. The explanation of this seems to be that the equal pressure lines begin to bulge out before the actual end of the nozzle is reached, as shown in the sketch (a). This increases the area of

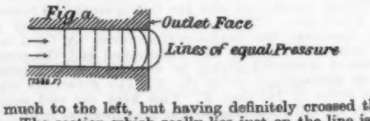


Fig. 9.

flow, and will permit of further expansion taking place beyond the theoretical limit. To avoid this uncertainty the F curve is not produced beyond the theoretical limit as represented by the acoustic line. This, of course, only applies to the full range expansions, the terminal points of the others present no difficulty. We have now three terminal points marked on the chart. By joining those up with a curve we get a flow curve to some scale, since for every point on this curve, A is constant and G the variable, varying with the pressure ratio of operation. This is the most valuable curve since from it we can get both the discharge coefficients and the nozzle efficiency. The top curve in the calculating chart is the theoretical value of F with $k = 0$. By comparing the actual value of the jet function at any pressure ratio as obtained from the flow curve with the theoretical value at the same ratio we get the discharge coefficient. Thus a curve of discharge coefficients on a base of pressure ratio of operation can be easily drawn.

An efficiency curve on the same base can be obtained with equal facility. On the chart is drawn a line of $\left(1-r^{\frac{n-1}{n}}\right)$. The theoretical velocity developed with expansion down to any pressure ratio r is proportional to $\left(1-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}$ and the energy is $\propto \left(1-r^{\frac{n-1}{n}}\right)$. The actual velocity and energy are $\propto \left(1-k-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}$ and $\left(1-k-r^{\frac{n-1}{n}}\right)$ respectively. The efficiency is therefore

$$\eta = \frac{1-k-r^{\frac{n-1}{n}}}{1-r^{\frac{n-1}{n}}}$$

By reading k from the flow curve and taking the value of $\left(1-r^{\frac{n-1}{n}}\right)$ the efficiency for any pressure ratio of operation can be obtained at once.

The discharge and efficiency curves for nozzle A with polished surface are shown in Fig. 8. The maximum efficiency is about 90 per cent., gradually falling as the pressure ratio is reduced. This is contrary to what might be expected; it would appear natural that at the lower speeds of the higher pressure ratios the losses would be proportionately less severe, evidently the reverse is true. The discharge coefficient also shows a downward tendency but, of course, not to the same extent. It should be noted that the discharge coefficient is not the square root of the energy coefficient but something less. This is due to the reheating effect of the loss increasing the specific volume and so reducing the flow.

Fig. 9 shows the same curves for nozzle A roughened. Measured on the theoretical standard the efficiency is reduced 3·5 per cent., but measured on the actual nozzle performance the reduction is about 4 per cent. The same downward tendency in the curves is again evident. Fig. 10 shows the discharge and efficiency curves for nozzle B. Exactly the same features are reproduced here and Fig. 11, showing the same curves for B roughened, has nothing new to offer. The reduction in efficiency with roughening is about 3½ per cent. on the theoretical, or 4 per cent. on the actual, nozzle performance.

These figures agree with those already found for nozzle A. The surface, then, plays quite an important part in the nozzle efficiency. Unfortunately it was not possible to test a nozzle with a plain cast surface, but judging from the reduction in efficiency with filling, the cast surface would have been probably 6 per cent. to 8 per cent. worse than the polished. However, this is not the only type of loss found in the nozzle.

ON DELAYED CRYSTALLISATION IN THE CARBON STEELS: THE FORMATION OF PEARLITE, TROOSTITE AND MARTENSITE.*

By A. F. HALLIMOND, M.A. (London).

THE equilibrium relations of α-ferrite, cementite and austenite present, as is well known, a close analogy with those of two mutually insoluble solids crystallising from a liquid solution. This analogy has provided a convenient basis for the description of the microstructures exhibited by those constituents in slowly cooled steels. Of recent years, however, the active prosecution of research on quenching has rendered it necessary to discuss the growth of structures, such as martensite and troostite, that have no counterpart among those formed by crystallisation from a liquid under approximately reversible or "equilibrium" conditions. In such cases it is necessary to take into account the principles governing "delayed crystallisation"; these have been established chiefly as the result of a series of researches by Miers, Barker, and other workers during the last twenty years, and have not yet had time to receive full treatment in most textbooks. The author has therefore ventured, before dealing with the carbon steels, to give in the first part of this paper a somewhat more detailed summary of that work than would otherwise have been necessary. In the second part an attempt has been made to indicate the lines on which these principles may be applied to account for the structures developed in carbon steels; the accurate thermal and other investigations required have recently been made available in the detailed researches of Portevin and others, and reference has been made to this work in discussing the delayed critical points and corresponding structures in terms of the supersaturation theory.

The view that the doubling of the critical points might be attributable to delayed crystallisation is not new, for this was already suggested by Miers in 1907 as a possible explanation of the doubled critical points observed by Roberts-Austen in certain alloys during solidification. Moreover, in the same paper, which deals with the freezing of a binary mixture, the conditions governing the appearance of crystals of each constituent are defined, and the possible variations in the order of crystallisation indicated. Again, of recent years, Stead, Portevin, and other workers have used the principle of inoculation by more or less "isomorphous" nuclei to account for the premature precipitation of cementite and the growth of ferrite in the neighbourhood of inclusions. Finally Portevin has given an outline of certain continental work on delayed crystallisation, with reference to the devitrification of glasses, but this does not include any account of the English work above mentioned. No general application to the crystallisation of steel has so far been given, and the present account has therefore been prepared in the hope of stimulating interest, and of providing material for the discussion of these questions. The development of a systematic treatment of this subject seems a necessary preliminary to the microstructural investigation of the special steels.

In considering the influence of the rate of cooling upon microstructure, three main principles must be taken into account. The first concerns the existence, below the ordinary solubility curve for each constituent, of a range of temperature and concentration within which crystallisation is only initiated upon the introduction of a suitable nucleus. The second is that the rate of growth of a crystal at first increases as the temperature falls below that of equilibrium, and then diminishes when a certain degree of supercooling is exceeded. The third is that the redistribution of heat and of dissolved matter, consequent on, and essential to, solidification at the surface of a growing crystal, is governed by gradients of temperature and concentration which depend in their turn upon the respective coefficients of heat conductivity and of diffusion.

Recent Researches on Delayed Crystallisation and Inoculation.—The fact that many carefully supercooled solutions would only crystallise on the introduction of a nucleus has long been recognised. Measurements by Tammann indicated that the period of duration of this condition diminished as the temperature at which the solution was held fell below the normal saturation point, at which solid and liquid can permanently coexist. The tendency to crystallise* (like the crystallisation-velocity) increased at first with diminishing temperature and then again diminished, so that a fused substance cooled through this range with sufficient speed remained as an amorphous solid, i.e., a "glass." With moderate supercooling the nuclei appear rarely, or, as was shown by Miers and Ostwald, not at all within a period of many weeks' duration. Ostwald proposed the terms "metastable" for this condition and "labile" for that induced by a greater degree of supercooling, in which crystallisation, when once initiated, extends rapidly throughout the mass with the development of a characteristic shower of crystals. The metastable state was not at first regarded as being very sharply separated from the labile, but the sharpness of the boundary in certain cases was recognised by Ostwald. As the result of extensive researches by Miers and his co-workers, the observation first recorded by him in 1906 has been fully verified in the case of numerous compounds and mixtures. It is possible, under suitable conditions of experiment, to determine a sharply-defined boundary, termed the "supersaturation point," between the metastable and the labile states, and a solution in a sealed tube may apparently persist indefinitely in the former condition, though a fall of a few degrees in temperature will at once cause the precipitation of the labile shower. Two standard methods are used in these researches: (*a*) The slow cooling of a liquid, covered, if necessary, with oil to prevent inoculation by dust in the air. At a well-defined temperature the substance in supersaturation crystallises in numerous small crystals, termed the "labile shower." With many liquids (*e.g.*, sodium chlorate solution) mechanical stirring is necessary before the shower will appear. The changes in concentration are measured by means of the refractive index, determined by total reflection in a glass prism immersed in the liquid; when the shower appears the combined actions of the fall in concentration and the heat evolved cause a sharp diminution of the refractive index. (*b*) The second method consists in allowing the liquid to cool slowly in sealed glass tubes; with constant shaking many substances crystallise in a shower at the supersaturation point, but in certain cases it was necessary to place pieces of glass or heavy minerals such as corundum, garnets, &c., in the tube to increase the friction; this was particularly the case with the more viscous liquids. The results of the two methods are concordant, and when the supersaturation points for various concentrations are plotted upon the ordinary freezing-point or solubility diagram for a mixture or solution they are found to lie on a second curve, termed the "supersolubility curve," which lies below the ordinary equilibrium curve and follows a similar course, but is not necessarily strictly parallel to it. The space between the two curves represents the metastable state, that below the supersolubility curve, the labile state. A thin shower sometimes appears when a solution is shaken in the metastable state, owing probably to chance inoculation. If not shaken or stirred, the more viscous solutions can be brought far into the labile state without the appearance of a shower.

The extent of the metastable range varies rather widely for different substances. For cæsium nitrate in aqueous solution it is practically zero, for ice forming in salt solutions it is usually 1 deg. or 2 deg. C., while for $Na_2SO_3.7H_2O$ in aqueous solution it reaches 30 deg. C.

Miers indicates the importance of these effects in determining structures. If the supersolubility curves of the two constituents are plotted on the diagram for a binary mixture having a eutectic point, the two curves intersect at a point termed the "hypereutectic point." The conditions of crystallisation in such a simple mixture were investigated for mixtures of salol with betol: multiple critical points were observed in the neighbourhood of the eutectic, and reference is made to the bearing of the experiments on the genesis of eutectic structures.

Following the same line of investigation a series of researches was made upon systems of which the components crystallised in a continuous series of mixed crystals, and in a series of mixed crystals forming a eutectic with the other constituent. The supersolubility curves were determined, and in some cases the composition of the first mixed crystals formed at the beginning of the labile shower was ascertained. These differed in composition from the liquid, even when the supersaturation point lay below the solidus curve. Viscosity must here play a considerable part, however, in limiting the selective crystallisation of material, and the present observation does not seem essentially inconsistent with the observation of Day and Allen that the viscous felspar melts, when crystallised below the solidus, yield crystals of the same composition as the liquid and not zoned.

The remaining references in this section relate to investigations, mainly on dissolved salts, in all of which satisfactory values for the supersolubility curve were obtained by the methods described above.

When the solution of a substance is in the metastable state, crystallisation can be initiated at the surface of a suitable nucleus introduced from without or already present in the liquid. This nucleus must usually be a crystalline particle, either of the substance itself, or of an "isomorphous" body. The interpretation of the latter term has been much discussed, for detailed measurements show that, even in the case of crystals with close structural similarity, the actual dimensions of the space-lattice are characteristic for each substance; both angles and linear dimensions may vary widely within the same "isomorphous" group.

The nature of isomorphism and the conditions for parallel growth between different members of certain isomorphous series have been investigated by Barker. The method of experiment was extremely simple, a drop of solution of one salt being placed on a fresh cleavage or other surface of the crystal on which parallel growth might be expected to occur. Three types of growth were recorded: (1) "Zonal growth," by the deposition of a uniform crystalline layer over the whole surface of the inoculating crystal. (2) "Parallel growth," by the deposition of many small separate crystals in parallel position, scattered over the surface of the inoculating crystal. (3) "Irregular growth" of many small separate crystals on the surface of the inoculating body, but not in parallel position. The first is limited to pairs of substances with very nearly identical molecular volume; the second occurs between the majority of isomorphous substances, while the third is found in those cases where the two crystals differ most widely in molecular volume. An idea of the degree of similarity necessary for parallel growth between halide salts of the alkali metals may be formed from one of the extreme cases, in which RbBr., with a molecular volume of 49·30, yielded parallel growths on KCl which has the molecular volume 37·49.

The property of forming parallel growths is exhibited by many pairs of substances that are not capable of forming mixed crystals. It seems to be mainly dependent on the equality of molecular volume, or perhaps even on the equality of spacing in one or two directions only, for this would appear to be the determining factor in many cases of regular growth among minerals, in which crystals are arranged with such directions parallel.

As is well known, soldium nitrate crystallises in parallel on the cleavage surface of a piece of calcite. This has been examined, with many other similar cases, by Barker, and also by Miers and Chevalier, and by Beilby. In the metastable state the solution deposited parallel crystals, in the labile state the growth was irregular. The subject was taken up by Kreutz, who showed that sodium nitrate formed parallel growths on calcite and barytocalcite; lithium nitrate, on the other hand, would not make parallel growth on calcite, but readily did so on the isomorphous carbonates of manganese and iron. Comparison of the densities of these substances indicated again that similarity of volume is the chief factor and not similarity of crystal angles. A further interesting fact is observed by Barker, that calcite will always induce the precipitation of rhombohedral potassium nitrate, but that the crystals so formed are not in parallel position.

Chevalier observed that different minerals, especially galena, induced crystallisation in potash alum solutions at characteristic temperatures, while glass also acted as a nucleus, but only in the labile state.

In the light of the observations of Miers and Chevalier it seems legitimate to assume that in Barker's experiments the parallel growths represent, in the main, deposition from the metastable state and the irregular growths deposition from the labile state. We have therefore a range of conditions extending from a complete structural similarity that yields zonal growth as soon as the equilibrium curve is passed, to the non-isomorphous structures that usually only affect the solution when it has entered the labile state. For each foreign substance there will be a characteristic temperature at which it is capable of initiating crystal growth.

It has been recognised, by Miers and other workers with the same methods, that the determination of the supersaturation point may be affected by inoculation. The glass sides of the vessel, the surface of the liquid, and the platinum stirrer are all potential sources of inoculation, but it is shown that the point is but little affected by the conditions of experiment. The addition

* Paper read before the Iron and Steel Institute, on Friday, May 5, 1922.

* Measured by the number of nuclei appearing in unit time in unit volume.

of mineral crystals to the tube experiments is apparently more dangerous, and Jones considers that differences in the determined supersaturation points for ice are due to the use of garnets in the tubes. It is even possible for glass to induce parallel growth; thus a drop of potassium nitrate melted under a cover-glass on a microscope slide crystallises with a granular structure in which the principal axis of each grain is nearly perpendicular to the cover-glass. Sometimes scattered, irregularly orientated grains are seen, and it seems clear that crystallisation has then begun at a few nuclei, while with a further drop in temperature the remainder of the nitrate solidified in parallel growth on the glass.

Even in the production of a labile shower, the number of nuclei formed is finite, and it must be recognised that the occurrence at a given point of the necessary condition for spontaneous crystallisation or for inoculation is dependent upon the lapse of time; the probable explanation of this lies in the occurrence of deviations from the average state of a fluid in the manner indicated by the kinetic theory. Nevertheless, the probability of crystallisation in many cases increases so rapidly with falling temperature that the labile shower has the appearance of being instantaneous, while even the formation of scattered crystals on an inoculating surface is subject to definite limits. In both cases, however, the number of nuclei can be diminished by sufficiently rapid cooling; thus sharply-defined points are characteristic of rapidly crystallising bodies, and in cases where crystallisation is particularly slow, as in glasses, the supersaturation point is represented by a range of temperature in which the number of nuclei appearing undergoes a rapid increase. On the whole there seems ground for regarding the true supersaturation or inoculation point as a definite limiting temperature, above which crystallisation will not occur even on indefinitely slow cooling.

In steel, crystallisation takes place obviously in the complete absence of stirring, the only analogue of this being violent mechanical working of the sample. The transport of material and of heat by convection and the introduction of nuclei from outside are alike eliminated. The supersaturation point, which is often only developed on vigorous stirring in fluid solutions, is therefore not necessarily developed at all in steel, and it is not permissible at once to identify the point at which any particular recalescence begins with the supersaturation point of Miers. With relatively slow cooling we are much more likely to encounter the specific inoculation points characteristic of the various crystals present, and of the intergranular surfaces; in the steels now under discussion it is an almost invariable rule that the grains of a new constituent originate at surfaces and not in the body of the austenite. The criterion of the supersaturation point, if present, is the appearance of a shower of small crystals; in two cases only does this occur in steel, namely, on the formation of troostite and of martensite. The temperatures of formation of these constituents are therefore taken to represent the supersaturation points of austenite with reference to cementite and α-ferrite respectively, and the remaining recalescence points are regarded as originating in inoculation, at specific temperatures, by the surfaces from which the new constituents begin to grow.

Linear Crystallisation-Velocity and Crystal-Habit.—The speed with which a growing crystal face advances normal to itself is termed the linear crystallisation-velocity. When a solution is only very slightly supersaturated the rate of crystal growth is small, and the habit of most crystals tends to be compact and symmetrical. It is under these conditions that the external form can accommodate itself to the condition that the surface energy shall be a minimum. When the degree of supersaturation is greater it would appear that growth is controlled by two factors; the diffusion of material into the approximately saturated layer in contact with the growing face, and also a definite heterogeneous reaction velocity conditioning the deposition of material. The latter would seem often to be the principal determining factor in the resulting crystallisation velocity; it may vary widely for different modifications of the same substance, as with tridymite and cristobalite, and for different faces of the same crystal. The result of the latter difference is that a crystal growing in a supersaturated solution often exhibits a tendency to growth in certain directions only, so that the normal crystal habit gives place to pronounced acicular or tabular growth.

It was shown by Tammann that this crystallisation velocity at first increases as the supercooling increases, then remains constant, and finally diminishes more or less sharply with falling temperature, probably owing in the first place to the usual increase in speed of a reaction with departure from equilibrium, and in the second place to the increase of viscosity and diminution of reaction velocity with falling temperature. The subject has been summarised from the crystallographic standpoint by Ritzel, and, from the standpoint of glass-making, by Portevin.

Diffusion of Heat and of Material.—The continued growth of a crystal is conditional on the maintenance of a supply of material by diffusion, and on the dissipation of the latent heat developed in crystallisation. In the case of a pure substance the former effect does not come into account, and Tammann regarded the above-mentioned increase in rate of crystallisation with supercooling as due simply to the second cause; the latent heat developed on crystallisation sufficed to raise the temperature at the growing surface to a point near the true solubility curve, and further growth only proceeded as heat diffused away to the cooler parts of the solution.

Steel represents a somewhat extreme case, in which the heat conductivity of the metal is great, while the coefficient of diffusion of carbon in γ-iron can hardly be regarded as more than that of a salt in water. Crystal growth will therefore take place under relatively isothermal conditions as regards the interior of the steel, the temperature of the surface of a growing constituent differing but little from that in the interior of the grains. Crystallisation thus proceeds at any moment at the temperature recorded pyrometrically for the mass of the steel.

The transition from approximately equilibrium crystallisation to a condition in which the structures begin to show very definite evidence of incomplete adjustment in concentration during the range Ar3–Ar1, occurs in the neighbourhood of the critical rate of quenching, as determined by Portevin in his work on the delayed critical points. That author records that at rates of cooling which yielded troostite the free constituents still separated in the non-eutectoid steels. With faster quenching the austenite areas fail to contract with separation of the free constituent, and the whole sample is obtained in the martensitic state. In ordinary slow-cooled steels, therefore, it must be admitted that the readjustment of concentration has time to proceed nearly to equilibrium, and that the composition of the austenite areas does not vary to any great degree from the centre to the margin.

The laws governing the diffusion of material are analogous with those governing the diffusion of heat. The development of temperature gradients in cooling solids has recently been discussed mathematically by Williamson and Adams, and the analogy between concentration and temperature gradients is referred to by Bowen. Detailed reference to this question will not, however, be required here, and it will suffice to refer to these recent publications.

Crystallisation in Ordinary Carbon Steels.—An endeavour will next be made to ascertain how far the crystallisation of the ordinary steels can be explained in terms of the supersaturation theory outlined in the preceding sections. Fig. 1 represents part of the usual iron-carbon diagram. $o\,a$, $o\,b$ are the equilibrium curves for α-ferrite and cementite in contact with austenite; they meet in o, the eutectoid point, at a temperature of about 725 deg. C. Below these curves have been represented various lines required by the supersaturation theory. $o'\,a'$, $o'\,b'$ are the supersolubility curves below which martensite and, in part, troostite, are formed. The point o' is the hypereutectoid point (following the nomenclature of Miers). The metastable range for α-ferrite lies between the lines $o\,a$ and $o'\,a'$; that for cementite between the lines $o\,b$ and $o'\,b'$. The areas below $o'\,a'$ and $o'\,b'$ are the labile regions for α-ferrite and cementite. In the area $o\,p\,o'\,q$ both α-ferrite and cementite are metastable; in the presence of nuclei both constituents will grow simultaneously, and so this area represents those temperatures and concentrations at which eutectoid structure can develop. It will therefore be termed the "eutectoid area." $f\,F$ represents the inoculation line at which nuclei of α-ferrite appear on the intergranular surfaces of austenite. $c\,C$ is similarly the line at which nuclei of cementite appear on the austenite surfaces. These indicate the points at which the free constituents first crystallise in cooling samples. The remaining two points represent the temperatures C′ at which cementite nuclei appear on the surface of free α-ferrite crystals,, and F′ at which α-ferrite nuclei appear on the surface of free cementite crystals. These are the temperatures at which the eutectoid crystallisation begins in hypo- and hyper-eutectoid steels.

All the points of delayed crystallisation, especially those of inoculation, are depressed with increasing speed of cooling. The values given in the diagram correspond roughly with those for small samples about 16 mm. in diameter, and have been based on the critical points given by Portevin and Garvin.

Let a medium carbon steel d_1 (Fig. 1) cool slowly until the ferrite line is passed. In the absence of nuclei no free ferrite will appear till a point f_1 is reached at which innoculation occurs on the intergranular surfaces of the austenite. This occurs at a temperature far above that at which shower-precipitation takes place. The ferrite separates at the grain boundaries,* with recalescence (Ar3,2), and the remaining austenite has the composition g. With further cooling the ferrite grows and the austenite reaches the eutectoid composition o, but in the absence of nuclei no precipitation occurs and the concentration continues to increase until a point C′ is reached at which cementite appears by inoculation on the ferrite surfaces. The interior of the austenite inevitably lags somewhat in composition below the surface, and so the state of the austenite grains is best represented by a horizontal line C′l. This is within the eutectoid area, and growth of pearlite at once sets in with recalescence. Provided the rate of cooling is not too slow, the steel remains below the line $o\,c'$ and continuous growth of grains of pearlite results. The temperature attained in the recalescence is from 690 deg. to 700 deg. C., while the growth of pearlite originates at about 680 deg. C. This temperature is distinctly higher than the troostite recalescence point, and there is no reason to suppose that in slow cooling the margins of the austenite undergo a shower-precipitation, though this condition may be very nearly approached. In other words, the point C′ is within the metastable range and growth is initiated by inoculation.

Let steel d_2 (Fig. 1) cool slowly until the cementite line is passed. In the absence of nuclei precipitation will not begin until a point c_2 is reached, at which free cementite grows by inoculation on the intergranular surfaces of the austenite. At this point the remaining austenite assumes the composition h_1 and, when the eutectoid temperature is reached, has the composition o. Ferrite does not appear until F′ is reached, at which α-ferrite appears at the cementite surfaces. Nuclei of both constituents being present in the eutectoid area, growth of pearlite occurs with recalescence. The crystallisation is initiated at about 665 deg. to 675 deg. C., or at higher temperatures with slower cooling, and the recalescence point is about 710 deg. C. On account of the great steepness of the line $o\,F'$ the interior of the austenite has nearly eutectoid composition, and the temperature of eutectoid crystallisation can consequently rise further toward the eutectoid point 725 deg. C., than in the hypoeutectoid steels.

It is clear that within a certain range of composition above and below the eutectoid point the austenite formed after separation of the free constituent will be at once in a condition for initiating the growth of pearlite at the points C′ and F′. Within this range there will be overlapping of the critical points, and a tendency to irregular distribution of the ferrite. The steels will all appear to consist almost entirely of pearlite.

The initiation of crystallisation in eutectoid steels only occurs when the lines $f\,F$ or $c\,C$ are reached. The temperature at which recalescence begins will therefore here reach a minimum, but formation of pearlite will proceed freely when once started. For the same reason a steel somewhat below the eutectoid composition can the more easily be cooled out without the appearance of free ferrite or troostite.

It will be observed that if the recalescence initiated at C′ carries the austenite to a state represented by a point above the line $o\,C'$, the growth of ferrite will cease, for the austenite is no longer metastable with respect to ferrite. Cementite, however, will continue to grow on existing nuclei. In the cases discussed above, the speed of cooling is assumed to be sufficient to keep the conditions below $o\,C'$; if, however, the austenite has attained the state C′ throughout, either by slow cooling as in a large casting, or by long diffusion in a small area between the points Ar3 and Ar1, as in a low carbon steel, the recalescence will carry the temperature above $o\,C'$ and carbide alone will crystallise on the margins of the austenite. Meanwhile the interior will be brought back by diffusion and cooling to a point within the line $o\,C'$ but nearer o, and will crystallise as pearlite. Cementite margins of this nature are well known, and have been attributed to "divorce" of the pearlite, but this explanation fails to account for the relatively greater frequency of the effect in the low carbon steels.

In the preceding account two distinct types of pearlite formation have been indicated, occurring near the points F′ and C′, for hyper- and hypo-eutectoid steels respectively. This corresponds, as above explained, with the well-known fact that the critical point is distinctly higher for the hypereutectoid steels than for those in which free cementite is not present.

The formation of eutectic structures was at first regarded by Miers as occurring in the neighbourhood of the hypereutectic point. Sections of preparations formed under such conditions have, however, generally indicated a finely granular structure corresponding with shower precipitation, and the characteristic interlocking of the constituents was rarely, if ever, obtained. It seems clear in the present case that the eutectoid structure is characteristic of growth in the metastable state, but at points which may lie very close to the equilibrium curves; the conditions for propagation of the structure being that the solution shall be metastable with respect to both constituents and that nuclei of both shall be present (*i.e.*, the representative point shall lie within the eutectic area $o\,p\,o'\,q$).

The removal of one constituent by crystallisation at once leaves the other in excess. The precipitation of the latter is then accelerated, and so the eutectic grain grows with a continuous boundary, even if the natural rates of crystal growth of the constituents differ considerably. If one constituent is present in predominant amount, the eutectic grains usually assume a crystalline form approximating to that of the dominant constituent. It is necessary to emphasise the fact that the eutectic structure has nothing in common with dendritic growth. The latter occurs in the lower part of the metastable range and has a highly distorted crystal habit. The eutectoid, on the other hand, is formed at temperatures but little below equilibrium, and may have a quite normal crystal habit for the dominant constituent. In the eutectic the interfaces between the constituents are often irregular or are of the nature of "combination-planes," while in free dendritic growths the outline is determined entirely by the symmetry of the one constituent concerned.

The form of the recalescence curve at Ar1 is extremely characteristic. It consists of a steep rise from the point of inoculation, followed by a period of constant temperature, after which cooling sets in as the crystallisation is completed. It is most significant that when the rate of cooling is increased the temperature of the level part of the curve is depressed, although the constancy of temperature is still maintained. The explanation of this is to be found in the fact that the rate of crystal growth increases as the temperature falls below equilibrium. This results in an increased rate of evolution of heat, and so for various rates of cooling corresponding temperatures exist at which the heat evolved in crystallisation balances the heat removed by cooling and constancy of temperature results.

As is well known, the more rapid the cooling of a sample the finer the pearlite; fine pearlite must therefore be regarded as characteristic of rapid crystallisation. It may be worth while to examine briefly the causes that determine the spacing of the pearlite lamellæ.

* The symmetry of a crystal forming from a liquid is determined by the structure of the crystal, but in the case of a crystal forming at the expense of another crystalline solid there is no reason to expect the form to depend on one body rather than on the other. In steel, in fact, both α-ferrite and cementite develop "along the cleavage planes of the austenite," and their shape is determined to a great extent by the symmetry of the latter.

Every growing crystal is surrounded by a film in which the concentration varies quickly from approximate saturation at the growing surface to the condition of the surrounding liquid. The steepness of the gradient in this film depends on the coefficient of diffusion of the crystallising substance. If two crystals approach close together they will compete for the dissolved material, and growth will diminish when they come within a range depending on the thickness of the surface layer. This is well seen when two dendrites meet in a crystallising drop; growth ceases, and there remains a clear space of liquid between the crystals. There is thus a limit within which two crystals cannot grow rapidly side by side. If growth is slow, diffusion operates to a considerable distance and the interspace is wide, but if growth is rapid the crystals can approach more nearly together and the dendritic structure has a finer grain. Now in pearlite the exposed surface of each cementite lamella grows by diffusion from the surrounding austenite; round each lamella will be a saturated zone, and should two lamellæ approach too closely their growth will be arrested; if, on the other hand, the lamellæ are too far apart, the cementite in the intervening region must be deposited on a fresh nucleus or on branches from neighbouring lamellæ. Thus for each condition of formation there will be a characteristic average spacing, which gets closer as the rate of growth increases.

Three characteristic temperatures govern shower precipitation in the labile state; they are: (1) The equilibrium point; (2) the supersaturation point at which the shower appears; (3) a point, or rather a range of temperature, below which crystal growth is completely arrested owing to viscosity or to lack of crystallisation velocity.

Recent researches have made it clear that martensite is a fine aggregate of α-ferrite crystals. The temperature at which this aggregate is formed, by a shower precipitation, is determined as about 350 deg. C. for approximately eutectoid steel, and is the recalescence point Ar″. It has been identified by Dejean with the point Ar3, depressed by extremely rapid cooling. This view is opposed by Portevin, who regards it as a point of "labile equilibrium," between austenite and a labile solid solution of carbide in α-ferrite. In the following note it will be treated simply as a supersaturation point analogous with those observed in solutions in which spontaneous crystallisation occurs without stirring.

Both Guillet and Portevin agree that the point rises with diminishing carbon content, so that the supersaturation curve $o'a'$ will have a course such as is shown in Fig. 1. The region of suspended crystallisation sets in below 100 deg. C., beyond which austenite undergoes little, if any, decomposition. When once the shower has appeared the supersaturation curve has no significance; there is thus no corresponding critical change on tempering. The latter consists in the grain-growth of α-ferrite and in the agglomeration of carbide, hence the close resemblance between the course of tempering and that of grain growth.

Troostite is encountered mainly in the higher carbon steels and in hypoeutectoid steels in which the austenite areas have approached eutectoid composition. On rapid cooling of the latter class the troostite appears only at the margins between the austenite and the ferrite while the interior passes into martensite. These grain margins represent regions in which the carbon is most concentrated, and troostite therefore seems to be a constituent only obtainable in the neighbourhood of the eutectoid composition.* The temperature of formation of troostite, Ar′, varies from 665 deg. C. in a high carbon steel to 635 deg. C. on rapid cooling. Beyond this stage the critical rate of quenching is reached and the point is not further depressed but vanishes, its place being taken by Ar″ at 350 deg. C. with formation of martensite. The physical properties of troostite show that it is a mixture of α-ferrite and cementite.

The formation of troostite may be explained as follows: On the supersaturation theory, shower precipitation of cementite will occur when a steel passes the line $o'b'$, the supersolubility curve for cementite. This curve, which will be roughly parallel with the equilibrium curve, is very steep, and so the low carbon austenites can only yield martensite. A further restriction is, however, necessary; since Ar′ cannot be depressed below 635 deg. C., it follows that at this temperature the range within which cementite cannot crystallise must supervene. The shower precipitation of cementite will therefore not originate below the troostite area indicated in Fig. 1. A patch of austenite of variable composition will thus be divided into two areas—the richer, which passes through the troostite area on cooling, yielding troostite, while the less concentrated yields martensite.*

The α-ferrite in troostite is in a relatively soft condition; it does not represent a ground mass of martensite, but must be supposed to have originated at the high temperature. The formation of this ferrite follows necessarily through inoculation by the cementite particles of the labile shower at some point a little below. It may be anticipated that with higher carbon steels the point Ar′ may be divided into two, one belonging to the cementite shower and one to the transformation of the residual austenite by inoculation at a lower temperature.

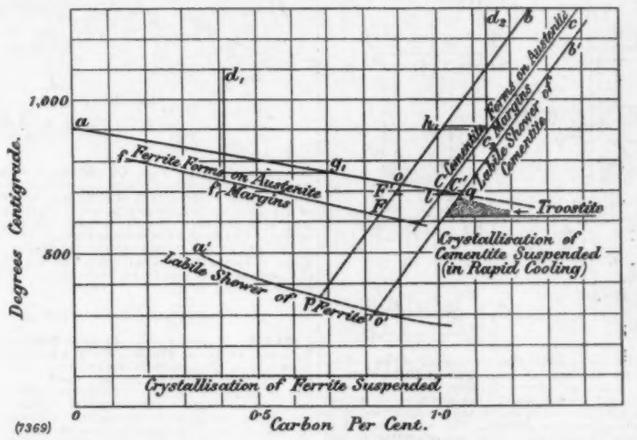


FIG. 1. DIAGRAM TO ILLUSTRATE DELAYED CRYSTALLISATION IN ORDINARY CARBON STEELS.

NOTE.—In order to simplify the diagram, the ferrite curve is represented as a straight line and the temperatures on the cementite curve are greatly exaggerated. The gradients near the eutectoid point are approximately correct.

THE MECHANICAL CONSTRUCTION OF THE MICROSCOPE.—A lecture on "The Mechanical Construction of the Microscope from a Historical Standpoint," given by Professor Alan Pollard before the Optical Society on April 27, at the Imperial College of Science, dealt with the evolution of the instrument from the earliest time up to about the middle of the nineteenth century. Professor Pollard divided his subject into two main periods, that of the non-achromatic, in which the early history of the single lens or simple microscope was dealt with, and the achromatic. The mechanical details of outstanding historical compound instruments in these two periods which marked the progress of mechanical construction up to that of the modern compound microscope, were described. Many famous instruments of the first period such as John Marshall's "New Invented Double Microscope" of 1693, Culpeper's "Double Reflecting Microscope" of 1735, Cuff's "Double Constructed Microscope" of 1744, B. Martin's simple and compound of 1765, Bleuler's "Universal" of 1788, Jones' "Most Improved" of 1798 by Dolland, Gould's pocket microscope by Cary of 1828, as well as Lister's famous compound microscope by James Smith in 1826, which marked the opening of the second period in this country, were set up with histological specimens so that their mechanical and optical performance could be compared. In addition to the above early catoptric instruments were shown, including Amici's reflecting microscope made for Dr. Wollaston in 1830. The development in particular of the modern English limb from the Lister and Jackson designs and the so-called Continental limb from the early forms of Oberheuser and Nachet was traced and described. The lecture was illustrated by lantern slides, and the historical instruments exhibited were loaned from the magnificent Court collection, as well as others in the South Kensington Museum, by the courtesy of the director, Colonel H. G. Lyons, F.R.S.

CATALOGUES.

Lifting Truck.—An illustrated leaflet, giving particulars of a lifting truck made in two sizes, comes from Mr. H. C. Slingsby, 142, Old-street, London, E.C. 1.

Thrust Bearings.—A catalogue, describing thrust bearings made with tilting segment blocks, comes from the Kingsbury Machine Works, Frankford, Philadelphia, U.S.A.

Oil Engines.—The English Electric Company, Limited, Kingsway, London, W.C. 2, send a copy of a catalogue describing the construction and action of the Fullagar oil engines as made for use on land.

Coal Dust Fuel.—The interest taken in firing with coal dust in the United States is exemplified by another catalogue we have received of the required plant, as made by the Grindle Fuel Equipment Company, Harvey, Illinois, U.S.A.

Concrete Pipes.—An extensive list of corporations and firms now using reinforced concrete pipes made by the Stanton Ironworks Company, Limited, near Nottingham, has reached us. Standard sizes are made from 4 in. to 60 in. diameter.

Oil-Well Drilling Tools.—A catalogue showing several types of drilling bits and other tools for oil-well boring comes from Messrs. Vickers, Limited, Broadway House, Westminster, London, S.W. 1, who supply all the necessary equipment for the work.

Water Power Plant Fittings.—Catalogues of a relief valve, a cylindrical balanced valve and buckets for impulse wheels have come to hand from the English Electric Company, Limited, Kingsway, London, W.C. 2. The method of attaching the buckets with one bolt, secure against backlash and accurately interchangeable, is interesting.

Baling Presses.—A leaf catalogue, with illustration and particulars of an hydraulic baling press for pressing groundnuts and other seeds, has reached us from Messrs. Hollings and Guest, Limited, Thimble Mill-lane, Birmingham. The nuts are crushed in their shells without damage to the kernels, being compressed to about half their original bulk, and the presses are delivered either in single units for hand-pump operation or in three unit batteries for power operation.

Irrigation.—A catalogue containing particulars of water meters and modules made by Messrs. George Kent, Limited; sluice valves and sliding gates made by Messrs. J. Blakeborough and Sons, Limited; and control sluices made by Messrs. Ransomes and Rapier, Limited, comes from the first-named firm, whose address is 201, High Holborn, London, W.C. 2. A well-written preface gives an account of ancient and modern irrigation works, especially Babylonian, Egyptian and Indian.

Electro-Medical Apparatus.—Three more catalogues of electrical apparatus for surgical use are to hand from Messrs. Watson and Sons (Electro-Medical), Limited, Parker-street, Kingsway, London, W.C. 2. These catalogues deal with intensifier screens for X-ray photography; an "ionostat" for furnishing continuous or galvanic current at low voltage from any ordinary direct-current electric light supply; and a radiological "ionometer" and other instruments for measuring X-radiation dosage in superficial and deep therapy.

Electric Motors.—Alternating-current motors of the induction type are the subject of a new 90-page quarto catalogue issued by Messrs. J. H. Holmes and Co., Portland-road, Newcastle-on-Tyne. Some useful notes of a general character, tables of approximate value of full load currents and all details of construction are given, and these are followed by tables giving the fullest possible information as to the variously modified forms in which the motors are made. This catalogue is very much in the nature of a handbook, and we may mention that it bears evidence of careful preparation, and that it is an amplification of similar publications which have previously proved to be very serviceable to electrical engineers.

Wood-working Machine.—Machines for planing wood have reached a very high degree of perfection, both as regards their design and construction and of quality of work produced. This is impressed upon one on an inspection of a catalogue to hand from Messrs. Thomas White and Sons, Limited, Paisley, which gives a good description, with several illustrations, of a machine made by them for finishing the four sides of a plank at one pass. The medium size will take planks up to 12 in. wide and 4 in. thick, forming flat, moulded or matching surfaces, and the rate of feeding the work is 120 ft. per minute. This machine weighs 4½ tons net and requires 25 h.p. to drive it. One larger and one smaller size of machine are made, and also one of a special design for producing flooring boards at much quicker feeds, viz., up to 300 ft. per minute.

Textile Mill Drives.—A catalogue dealing rather comprehensively with this subject has been issued by the Metropolitan Vickers Company, Limited, Trafford Park, Manchester. Mill drive by steam turbines, electric drive by shafting and belt or ropes for a limited area, and individual drives for large numbers of looms in one mill, are all shown and recommended for certain applications, but we gather that the firm regard the individual drive system as generally superior. Financially the question is different where a new mill is to be built and equipped, or where additions or alterations to a fairly efficient existing mill have to be made, but the causes that determine the choice of system in the former case are also operative in the latter. The point at which older systems should be scrapped is always difficult for the millowner to decide, and the engineer can only offer advice which must be well founded on economic grounds.

* This refers only to the troostite formed in directly-cooled steels, and not to the fine temper structure also sometimes called by this name. In the same way "pearlite" is used with reference only to the eutectoid aggregate and not to any aggregate of cementite and ferrite, however derived.

* These remarks relate to the rapid cooling necessary to bring the sample past the condition at which pearlite forms. If, by interrupting the quenching, the steel is held for some time below the troostite area but above the martensite point, troostite will appear, as shown by Portevin and Garvin.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the communicators are given in italics.

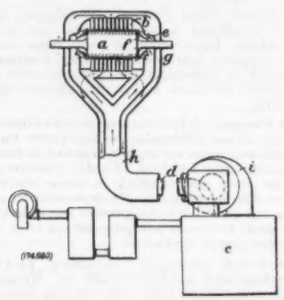
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 1s.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

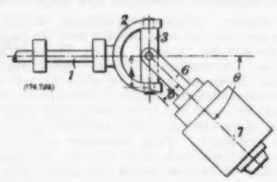
174,693. W. M. Selvey, Sheffield, and L. R. Moorshead, Westminster. Cooling Dynamo Electric Machines. (1 *Fig.*) October 22, 1920.—This invention has reference to the cooling of dynamo electric machines by passing through ventilating spaces in the machines, air which has been cooled in a refrigerating system. According to the invention, the cold air delivery passages are enclosed within the warm air return passages. *a* is the rotor and *b* the stator of the machine to be cooled, both formed with ventilating ducts; *c* represents a refrigerator through



which air is circulated, the flow of cooled air being by way of an inner pipe *d* delivering the air to chambers *e* at the ends of the machine, and thence to fans *f* on the ends of the rotor *a* which project it against the ends of the stator and into the air gap between the rotor and stator, whence it escapes through radial ducts in the latter into a surrounding casing *g* connected to a trunk *h* leading the warmed air back to the refrigerator for re-cooling. *i* is an air-circulating fan which may be used in place of, or in addition to, the fans *f*. (*Sealed.*)

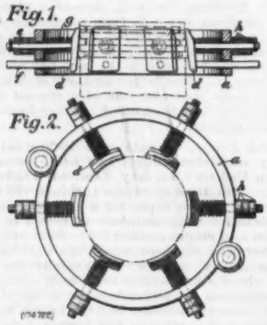
GAS ENGINES, PRODUCERS, HOLDERS, &c.

174,758. F. W. Lanchester, London, and The Daimler Company, Limited, Coventry. Internal-Combustion Engines. (1 *Fig.*) November 4, 1920.—This invention relates to magneto ignition for internal-combustion engines. The invention consists, in brief, in arranging the magneto-shaft 7 at an angle to the shaft 1 by which it is driven, and connecting



the two shafts by a single Hooke's joint 2, 3, 6, in such manner that the irregularity of angular motion produced by the Hooke's joint is utilised to give the magneto shaft a higher speed, or speed above its average, at the period when the ignition current is being generated and the primary break takes place. (*Sealed.*)

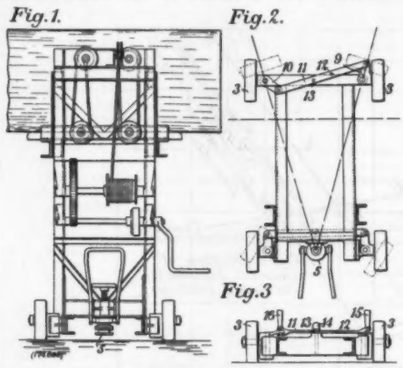
174,722. A. L. Pannell, Caversham. Inserting Pistons into Cylinders. (3 *Figs.*) October 30, 1920.—This invention relates to tools for facilitating the insertion of pistons and their piston rings into cylinders, and, according thereto, comprises an



annular member *a* to encircle the piston, and a circularly disposed series of jaws *d* carried by rods *e* and *f*, arranged to slide radially in the annular member. The operative faces of the jaws are inclined to the central axis around which they are radially disposed. Springs *g* are threaded over the rods *e* between the rear faces of the jaws and the inner surface of the annular member. Collars *h* are threaded on the lengths of rods *e* projecting beyond the annular member and are kept in position by split pins. The method of setting and using the tool is as follows: The thickness of the collars *h* is arranged so that the circumference of the circle included by the jaws at their inner limit of travel is either equal to or less than the circumference of the piston with which the tool is to be used. The tool is pressed over the piston and the latter pushed into the cylinder, or the tool is abutted against the foot of the cylinder and the piston pushed through it into the cylinder. It is obvious in either case that the piston should be entered at that side of the tool where the jaws are further apart. (*Sealed.*)

LIFTING AND HAULING APPLIANCES.

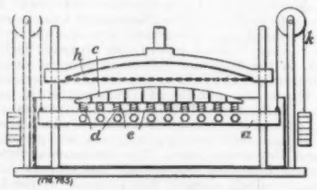
174,686. J. N. Goudie, Hunter's Quay, Firth of Clyde. Portable Cranes and Hoists. (4 *Figs.*) November 16, 1920.—This invention relates to portable cranes and hoists of the type including a base mounted on wheels and a vertical jib or platform guide equipped with a winch for raising or lowering the load. The primary characteristic of the present invention is the feature that the distal castor wheels 3 are provided with means whereby they may be locked with their axes disposed transversely to the normal direction of movement of the base, and whereby they may be locked with their axes disposed in radial line with the pivotal member. The locking means comprise oppositely-directed steering arms 9, 10, secured to the castors 3, and a rod 11



connecting the arms in suchwise that movement of the rod 11 is accompanied by simultaneous movement of the castors in opposite directions into one of two positions, *i.e.*, one in which the axes are disposed transversely to the direction of normal movement of the base, and one in which the axes are arranged in radial line with the pivotal member 5. The connecting rod is provided with two perforations 12, 13, corresponding to the positions aforesaid and adapted to register with a perforation in the base with which is associated a locking pin 14 for locking the rod against movement relatively to the base. 15, 16 denote handles for manipulation of the castors 3. (*Sealed.*)

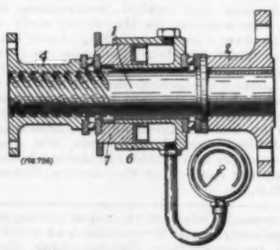
MACHINE AND OTHER TOOLS, SHAFTING, &c.

174,765. Cocker Brothers, Limited, Sheffield, and F. M. Moody, Sheffield. Plate-Bending Machines. (1 *Fig.*) November 6, 1920.—This invention relates to machines for making laminated springs, and is of the type in which an adjustable concave cambered head moving on vertical guides co-operates with an adjustable convexly-cambered block built up in segments in order that heated metal plates placed between them may be bent to the desired shape. The invention consists in making the top member in the form of a chain *h* with spring



or other extensible ends, and in forming the segmental blocks *c* of the bottom member with shanks *d* adapted to enter holes in a bed plate *a* which has tapped holes to receive set screws for engaging the shanks of the segmental blocks so as to hold them in any desired position. Surrounding the shanks are coiled springs *e* under compression, which tend to lift the segments. The bed or plate *a* carrying the bottom camber may be supported by means of cords *k* passing over pulleys and having heavy weights on their other ends. (*Sealed.*)

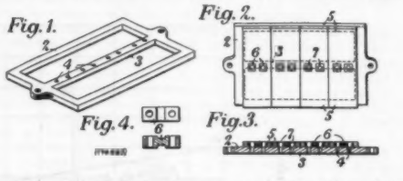
174,726. H. D. Bush, Greenhithe, Kent, and H. Merton-Caversham, Reading. Power Transmission and Power, Indicating Couplings. (1 *Fig.*) October 30, 1920.—This



invention relates to power transmission and power-indicating couplings, and refers particularly to apparatus for indicating or for producing a difference in angular relationship between two rotatable members. The invention relates to apparatus of the type comprising a coupling between the two rotatable members such that angular displacement between them produces proportional relative linear movement of the members towards and away from one another, or *vice versa*, and an expansible fluid chamber having two opposed relatively-movable walls engaged respectively with the two members, and means to indicate variations in the fluid pressure in said chamber. According to the present invention, the apparatus of the type described is characterised by the fact that the two rotatable members 2, 4 to be coupled are in direct screw-threaded engagement one with the other, and the fluid chamber is in the form of an annular piston-and-cylinder device 6, 7 surrounding, but not rotatable, with member 2, the two elements of the part 1 of the device being in direct endwise-thrust engagement, respectively, with the two rotatable members. (*Sealed.*)

MINING, METALLURGY AND METAL-WORKING.

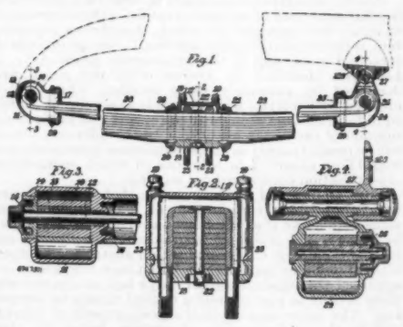
174,695. G. E. Roberts, Coventry, and J. E. Bates, Coventry. Pattern Plates for Foundry Moulding. (4 *Figs.*) October 25, 1920.—This invention relates to pattern plates for foundry moulding, and more particularly to such as are made in sections, any one or more of which may be readily changed or removed at will. The invention consists in casting each section with two or more bushes and in forming the pattern plate frame with corresponding holes adapted to receive removable pins passed through the bushes. The pattern plate sections each carry the



two parts of the pattern. On the one side the pattern plate frame 2 is formed with a central longitudinal member 3, which is drilled with a series of pairs of holes 4 for locating the sections 5 of the plate in their correct positions on the frame. For this purpose each plate section is provided with a corresponding pair of bushes 6 to receive the locating pins 7. The bushes 6 for each section are formed in pairs joined together at a fixed distance apart, as shown in the detail view, Fig. 4, so that when cast in the sections there can be no tendency for them to get out of position axially or relatively. (*Sealed.*)

MOTOR ROAD VEHICLE

174,750. W. Shackleton, Tinsley, Sheffield, and Sheffield Simplex, Limited, Tinsley, Sheffield. Springs. (8 *Figs.*) November 3, 1920.—This invention refers particularly to means for protecting vehicle springs and their associated parts from dust, moisture and the like. The type of vehicle spring-protecting device to which the invention relates is that comprising metal housings or casings for the points of attachment of the spring to the vehicle, which housings are provided with mouths to allow the spring to enter, and gaiters or sleeves of flexible waterproof material embracing the spring and tightly secured at their ends around said mouths. According to the present invention, the housing, which itself constitutes a shackle or link to connect the end of the spring with the chassis, is characterised by the fact that the housing completely encloses, or is combined with, means completely to enclose that part of the chassis (such as a pivot pin) on which the shackle is pivotally mounted. The drawings show the application of the invention to a front spring. The front eye of the spring is disposed within a housing 11. Through the eye passes a tiebolt 12, with a sleeve 13 interposed between the eye and the tiebolt. The outer lateral end of the housing 11 is closed by an enlarged end 14 of the sleeve 13, and a nut 15 which embraces the end of the tiebolt, as shown in Fig. 3, and the other (inner lateral) end of the housing conveniently bears against and encloses the inner face of the eye. The tiebolt is surrounded by a tubular member 16 extending



across the front of the car and engaging with its ends the inner lateral surfaces of the two similar housings 11, one for each front spring. The dumb-irons embrace the ends of the member 16 approximately at their junction with the housings 11, and are secured rigidly thereto. Each housing has a mouth 17, through which the spring projects, and the mouth is provided with a beaded rim. The centre or axle bracket of the spring constitutes a housing composed of upper and lower portions 117 and 18, bolted together. This housing has mouths 20 and 21 fore and aft, through which the spring projects, also provided with beaded rims. The spring laminations are conveniently secured at the middle by means of a bolt 22, and inverted. U-shaped stirrups 23 are provided for connecting the bracket to the axle. At the rear end of each front spring a housing 24 constitutes the shackle and is provided with a mouth 25, with a beaded rim through which the spring projects. The pin 26, which passes through the rear eye, is carried in and enclosed by the lateral end walls of the housing 24 and the upper pin 27 of the shackle has its bearings in a bracket 128 which is readily attachable to the chassis by means of bolts passing through orifices provided in the bracket and the chassis. The actual envelope for the spring between the housings consists of a sleeve of flexible waterproof material 28. The ends of each sleeve are shaped to fit over the mouths of the housings and are held in place thereon by wires. (*Sealed.*)